# Iron and Steel ENGINEER

ENGINEERING SERVICE TO THE IRON AND STEEL INDUSTRY SINCE 1907

JULY, 1948 TECHNOLOGY DEPARTMENT

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The EAN ENGINEERING Company, Inc.
WARREN, OHIO

SPECIALISTS IN SHEET, TIN & STRIP MILL EQUIPMENT

WEAN EQUIPMENT Corporation
Cleveland Ohio

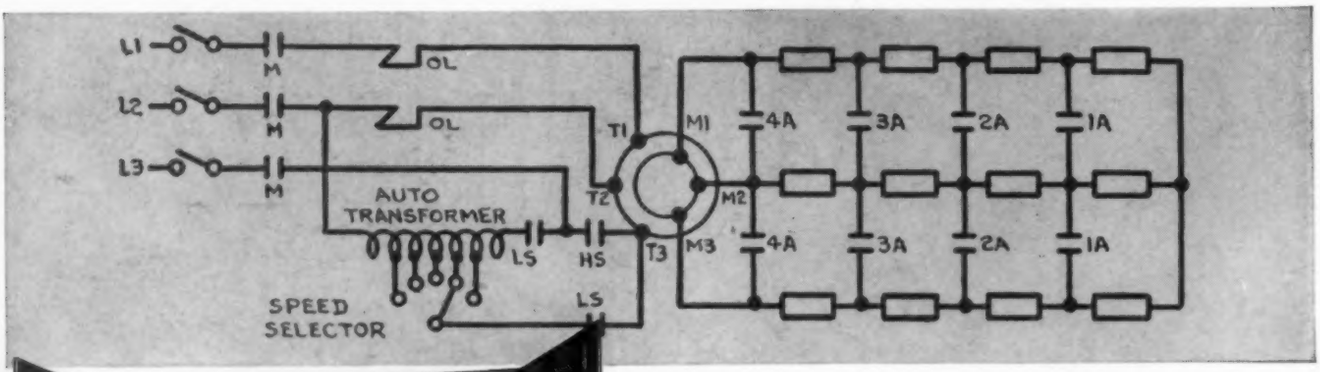
NARROW STRIP AND WIRE MILL MACHINERY

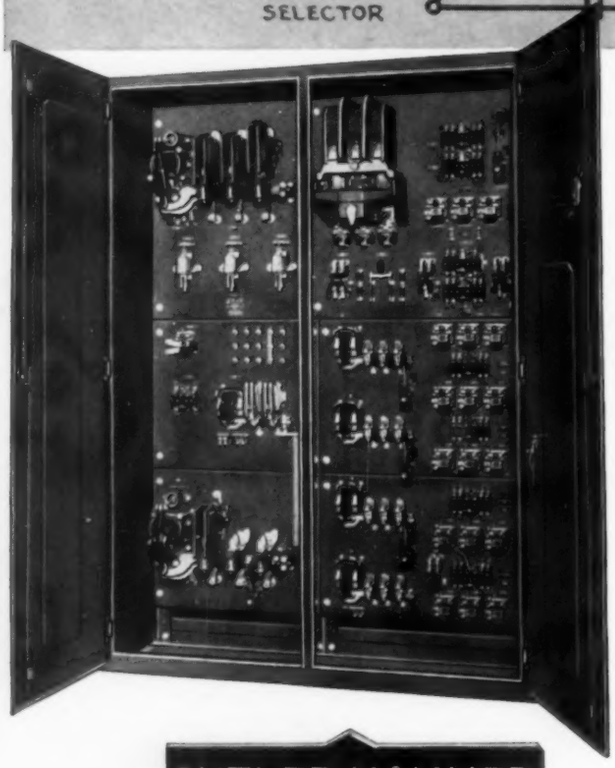
HOLMQUIST BARBED WIRE AND WIRE FENCE MACHINERY

√ R v. 25² July-Dec. 1948

**What control for what mill equipment?**

**One of a SERIES** of advertisements featuring basic heavy duty power circuits . . . and showing Cutler-Hammer's broad design and application experience which has made it the preferred control for the steel industry.



**Where an A-c installation calls for stable slow speed and dynamic braking**

# Specify CUTLER-HAMMER Custom-Built A-c Unbalanced Primary Control . . .

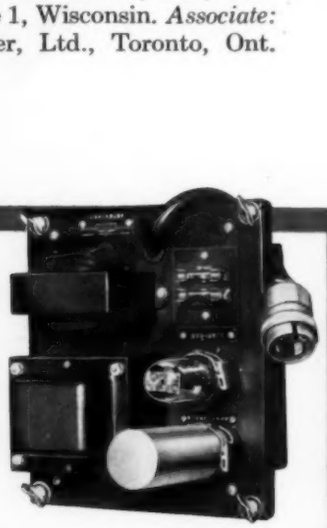
The Cutler-Hammer Unbalanced Primary Control permits a smoothly controllable reduction of speed and stable operation at any speed from standstill to synchronism . . . on slip ring wound rotor motors. This new yet fully tried and proved Cutler-Hammer control gives to alternating current motors, as for example on a draw bench, the same flexibility that could be gained otherwise only with direct current motors. Further information on this typical product of Cutler-Hammer specialization in motor control will be sent you on request . . . CUTLER-HAMMER, Inc., 1269 St. Paul Ave., Milwaukee 1, Wisconsin. *Associate:* Canadian Cutler-Hammer, Ltd., Toronto, Ont.

CUTLER-HAMMER
MOTOR CONTROL
C-H

**Typical Components of CUTLER-HAMMER Mill Control:**

200 ampere heavy duty safety switch.

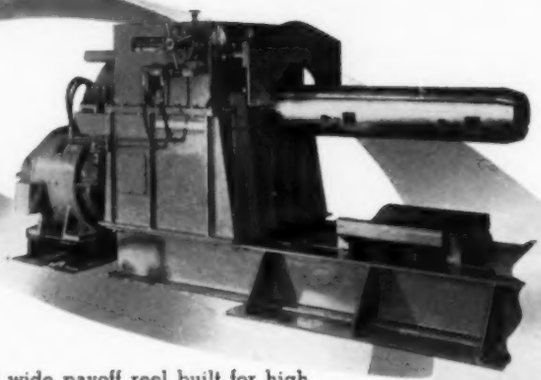
Magnetic limit switch.



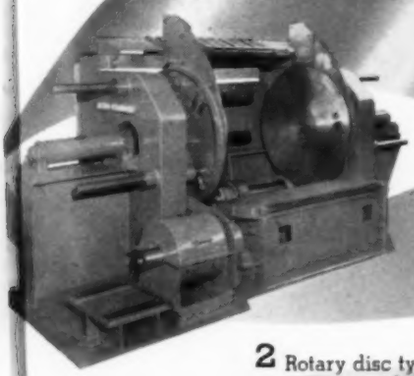
Quick-change unit panel, photoelectric limit switch.

IRON AND STEEL ENGINEER, published monthly by Association of Iron and Steel Engineers, 1010 Empire Bldg., entered as second class matter January 25, 1924 at Pittsburgh, Pennsylvania, under Act of Congress March 3, 1879. $7.50 per year in United States, $8.25 Canada, $10.00 foreign countries. Volume 25, No. 7.

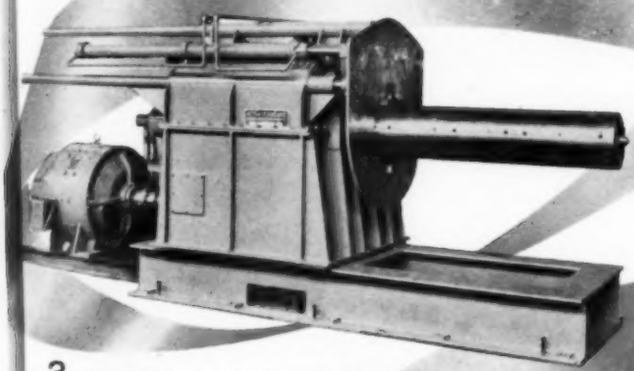
# 4 WAYS TO CUT *Coil Handling Time*



1 72" wide payoff reel built for high speed slitting line.



2 Rotary disc type coil box with quick opening side guards.



3 This 72" wide tension reel, companion of payoff reel, one of the largest ever built . . . for handling 72" wide coils of 30,000 pounds.

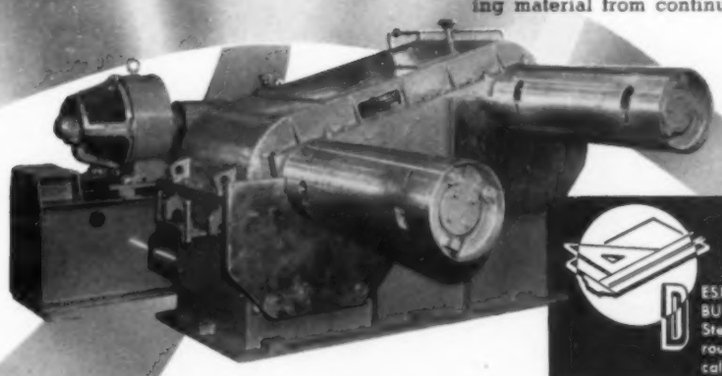
(1) Photographs shown represent some typical Aetna-Standard Coil Handling Units. This 72" wide payoff reel provides back tension control at high speeds. Loading or expanding movement controlled hydraulically, and a patented feature centers coils automatically. Handles up to 30,000 pounds in weight.

(2) This rotary disc type coil box has motor driven carrier rolls, and air operated side guides. The guides quickly open to receive a new coil, and return to a pre-set width. For handling hot rolled coils with a minimum of damage to material, look at this Aetna product.

(3) Companion unit to the payoff reel . . . a 72" wide tension reel arranged for either under or over winding with positive hydraulic expansion. For rewinding multiple slit material at high speed, stripper operates by air.

(4) The double drum tight coiler for rewinding material from continuous lines has many features . . . (a) selected gear drive and air stripping; (b) two reels for operations where large investments in single reels are not practical; and (c) made for any width material.

4 Double drum tight coiler for rewinding material from continuous lines.



DESIGNERS AND BUILDERS to the Steel, Non-Ferrous and Chemical Industries

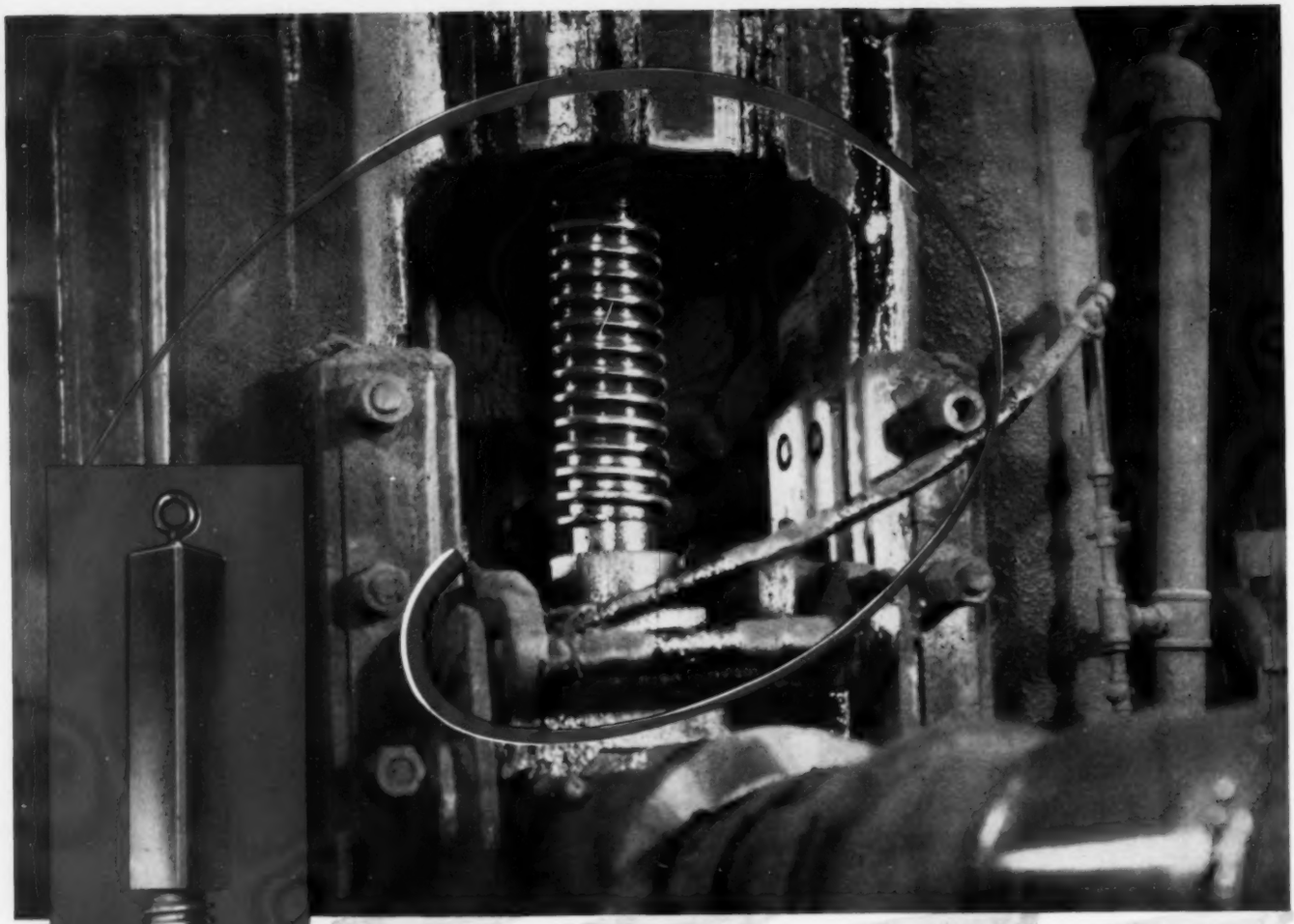
## THE AETNA-STANDARD ENGINEERING COMPANY

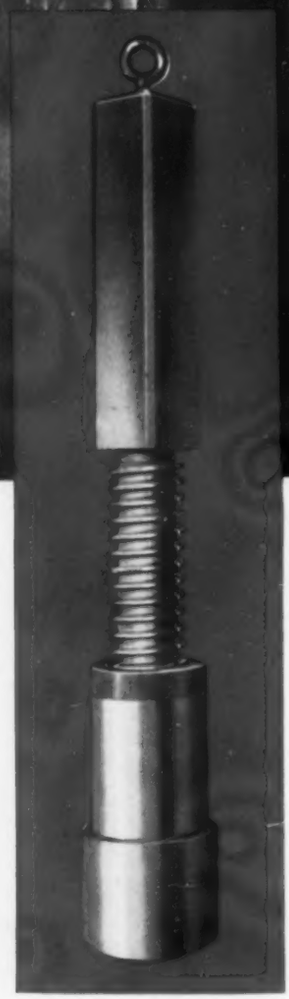
**YOUNGSTOWN, OHIO**

*ASSOCIATED COMPANIES:*

HEAD, WRIGHTSON & COMPANY, LTD., THORNABY-ON-TEES, ENGLAND

AETNA-STANDARD ENGINEERING COMPANY, LTD., TORONTO, ONTARIO, CANADA





# "TOOL STEEL" PROCESS SCREW DOWN SCREWS AND NUTS SLASH TONNAGE COSTS!

***Compare* these typical results:**

| BLOOMING MILL | | TONNAGE | SERVICE LIFE RATIO |
|---|---|---|---|
| 40" | "TOOL STEEL" SCREWS..... | 4,453,395 | 12 to 1 |
| | CARBON STEEL SCREWS ..... | 371,892 | |
| 36" | "TOOL STEEL" SCREWS..... | 3,495,515 | 3½ to 1 |
| | TORCH HARDENED SCREWS ..... | 985,055 | |
| 32" | "TOOL STEEL" SCREWS..... | 5,327,581 | 13⅓ to 1 |
| | CARBON STEEL SCREWS ..... | 400,000 | |
| 40" | "TOOL STEEL" SCREWS (World's Record) | 7,257,400 | 9⅓ to 1 |
| | CARBON STEEL SCREWS ..... | 783,741 | |

**"Tool Steel's" tonnage superiority has likewise been proved on plate and slabbing mills!**

**Greatly increase your tonnage through minimized "down-time"—investigate these cost-saving facts today!**

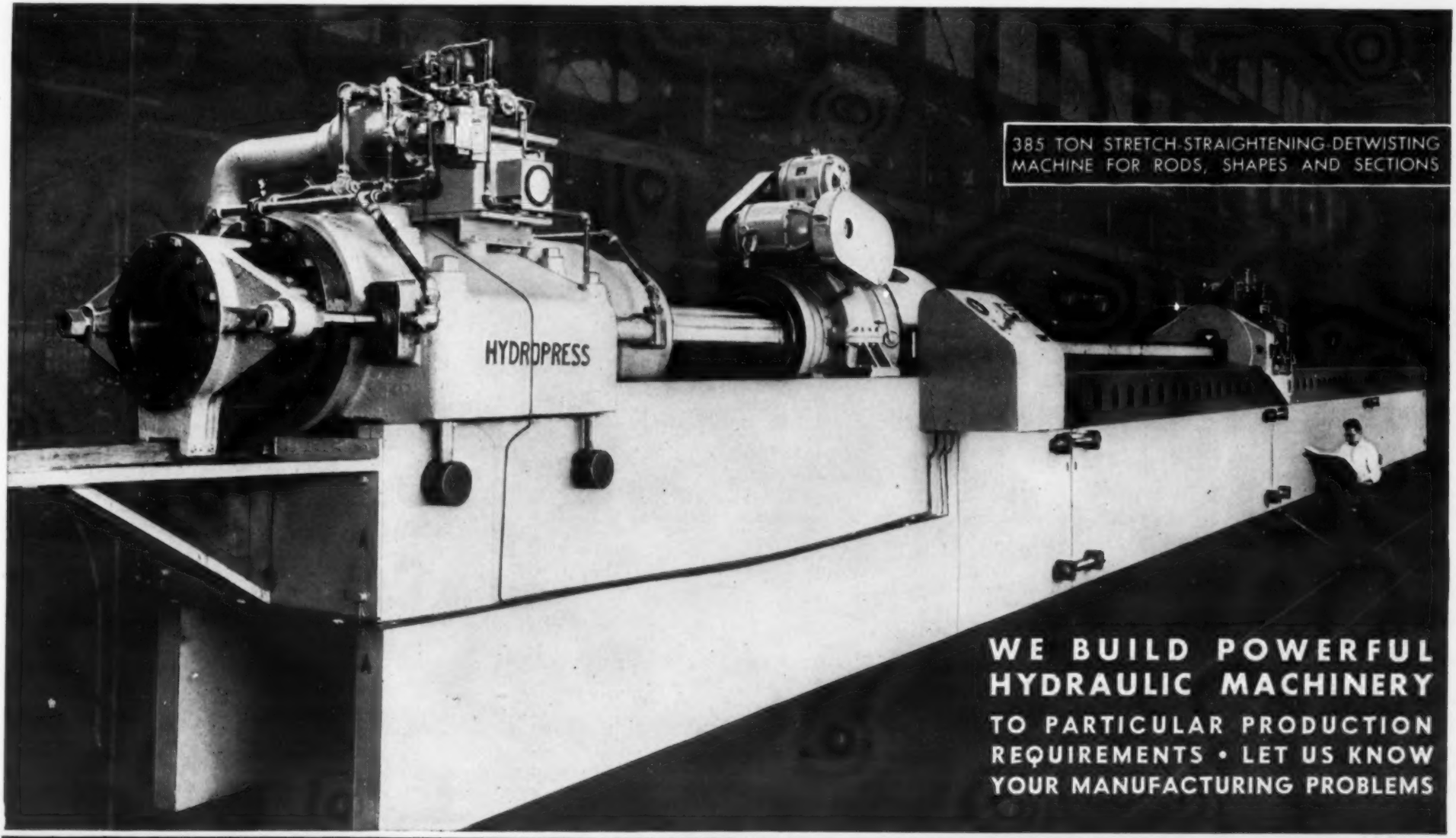
"TOOL STEEL" PROCESS

*The Standard of Quality*

*for* GEARS • PINIONS • ROLLS • SPROCKETS • WHEELS *and other* HARDENED PRODUCTS

## THE TOOL STEEL GEAR & PINION CO.

**CINCINNATI 16, OHIO**




HYDROPRESS · INC.

HYDRAULIC PRESSES · ROLLING MILLS · PUMPS
ACCUMULATORS · DIE CASTING MACHINES

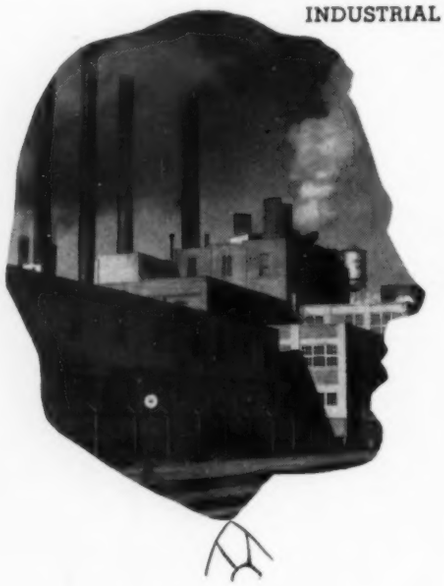
ENGINEERS · CONTRACTORS
566-568 LEXINGTON AVENUE
NEW YORK 22 · N. Y.
CHICAGO DETROIT SAN FRANCISCO SEATTLE
WASHINGTON D. C.

# Which Head Can Help You ?

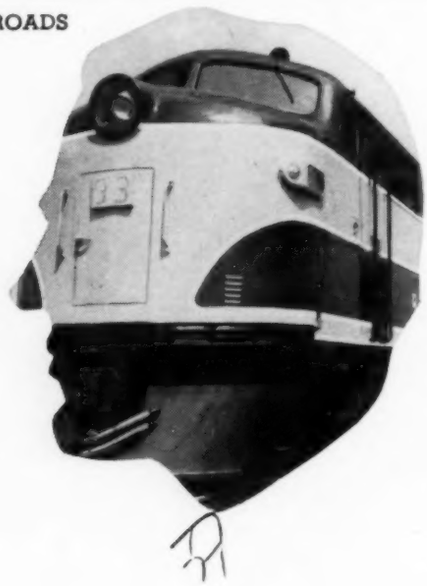
POWER PLANTS

STEEL MILLS

INDUSTRIAL PLANTS



RAILROADS



Rockbestos representatives are more than salesmen . . . they are seasoned, informed *Field Engineers.*

You can put a lot of faith in the judgment of your Rockbestos Field Engineer. He didn't get his "savvy" from books alone—but by getting out and getting around factories, power plants, steel mills and railroads.

Matter of fact, it's a big job for us just to keep up with him. He's seldom around his own office, because most of the time he's around your plant or office.

In short, your Rockbestos man has learned the answers to your wire and cable needs by working *in* your business, by working *with* your business, and by keeping constantly informed on your day-to-day requirements.

Use the service he can give you. It doesn't obligate you . . . either in fact or in spirit. It's reliable. It's experienced. Use it.

---

**Get your copy of the No. 10-F Rockbestos Catalog, 96 pages sectioned for easy reference — write today—to our nearest district office or direct:**

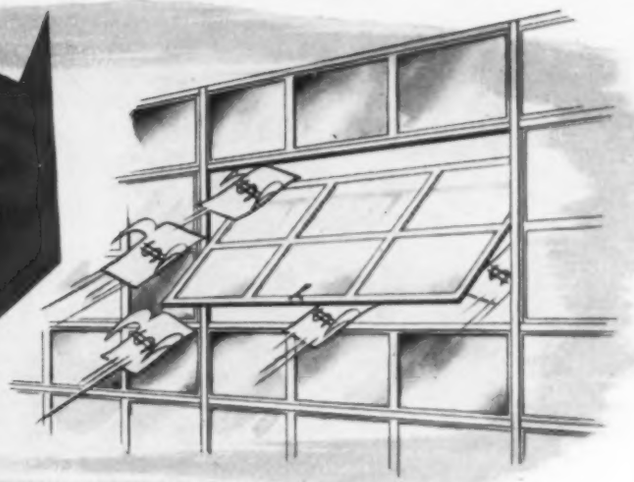
**ROCKBESTOS PRODUCTS CORP.**
636 NICOLL ST., NEW HAVEN 4, CONN.

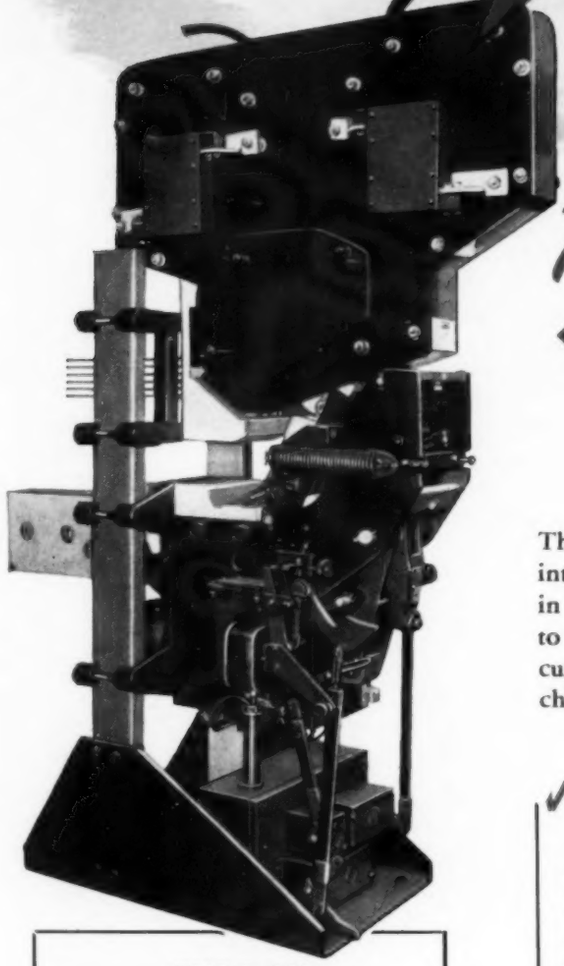
New York Buffalo Cleveland Detroit Chicago
Pittsburgh St. Louis Los Angeles Oakland, Calif.

**ROCKBESTOS**

**THE WIRE WITH PERMANENT INSULATION**

# How much would a shut-down cost you?





## Protect Production

**with this better-designed, better-built breaker**

Efficient production is a complete chain of operation. Obsolete electrical switchgear may be the weak link that can shut down your plant. Protect your production more effectively, more dependably, with I-T-E's Type MT Automatic Reclosing Circuit Breaker.

The MT is a rugged, effective breaker, specially developed for interrupting extremely heavy direct-currents. It breaks a circuit in .028 seconds (about 1¾ cycles on a 60-cycle basis) at 25% to 100% of interrupting capacity. Short circuits and overcurrents are cleared instantly, completely—before they have a chance to spread trouble.

### TYPE MT

Single pole . . . Electrically operated . . . Application Ranges: 250 and 750 V. D-C. Interrupting rating is 150,000 Amp. in capacities of 2000 and 4000 continuous ampere ratings . . . 250,000 Amp. in capacities 6000 Amps. continuous and above.

*Further information on the I-T-E Type MT is contained in catalog 2202. Send for it today.*

### NOTE THESE MT FEATURES

**RATE-OF-CURRENT-RISE TRIP**

Anticipates extremely high currents . . . Distinguishes between useful load of high value and a dangerous fault current . . . Trips breaker before danger peak is reached.

**TRIPPING DEVICES**

The MT is electrically and mechanically trip-free on overcurrent—trips immediately when closed on a fault . . . All tripping devices are direct-acting and instantaneous.

**BUFFER MECHANISM**

A specially designed, self-energizing buffer mechanism smoothly absorbs shocks of opening—prevents sticking or bouncing.

**MOUNTINGS**

Normally built in two styles: for pedestal mounting and for panel mounting. Also drawout-truck mounted in metal-clad switchgear.

The I-T-E Representative in your locality will be glad to advise you on applying the MT—and other I-T-E protective equipment—to your electrical distribution system. Use his services without obligation.

R&IE I-T-E*

# MILL TYPE SWITCHGEAR

## The Leader In Technical Excellence

I-T-E CIRCUIT BREAKER CO. — 19th & HAMILTON STS., PHILA. 30, PA. — 31 OFFICES IN THE U. S. & CANADA

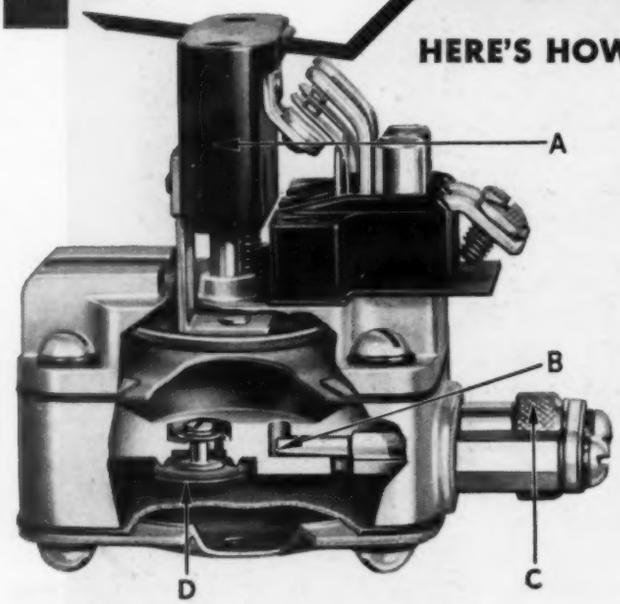
SWITCHGEAR • UNIT SUBSTATIONS • ISOLATED PHASE BUS STRUCTURES • AUTOMATIC RECLOSING CIRCUIT BREAKERS • HIGH SPEED CIRCUIT BREAKERS

*FOR POWER SWITCHING EQUIPMENT REFER TO RAILWAY AND INDUSTRIAL ENGINEERING CO. AN I-T-E SUBSIDIARY

# PNEUMATIC TIMERS Do It Better

# ACCELERATE MILL MOTORS ... and CONTROL AUTOMATIC PROCESSES

## HERE'S HOW THEY WORK



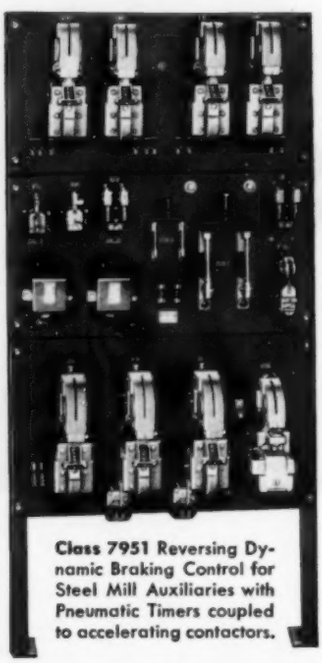

Timing head can be coupled to a contactor or actuated by separate magnet. Contact member (A) is normally pushed down against compression spring. When contact member is released, a rubber diaphragm is flexed upward, drawing air from lower chamber to upper chamber through metering orifice (B). Rotation of knurled wheel (C) advances or withdraws pin to give wide range adjustment. Air returns through valve (D) for instantaneous reset. Lower diaphragm is double layer felt.

**Square D's PNEUMATIC TIMERS, a product of over 10 years' experience in many difficult fields of application, offer these proven design and performance features.**

- **Extremely accurate**
- **Adjustable over wide range**
- **Unaffected by dust or usual fluctuations in voltage or temperature**
- **Dependable over long periods of severe service**
- **Simple, flexible and easily applied**
- **Attached to contactors or actuated by separate magnet**

• Accurate, fixed timing insures uniform motor acceleration under all conditions of application. Operators are able to obtain closer control by anticipating machine response. Unusually wide range adjustment permits choice of timing period to cover any acceleration requirement.

Processing of steel and associated materials consists of many individual operations performed in timed sequence. (For example—the interval allowed for dumping a blast furnace skip bucket before the hopper rotates.) Pneumatic timers are available for time-delay making or time-delay breaking of a circuit after either energization or de-energization of contactor or separate magnet. Their use in an automatic control circuit simplifies equipment and provides the accuracy and reliability essential to efficient performance.



Class 7951 Reversing Dynamic Braking Control for Steel Mill Auxiliaries with Pneumatic Timers coupled to accelerating contactors.

*Write for HEAVY DUTY DC MILL CONTROL CATALOG which includes complete information on the Pneumatic Timer and its uses: Square D Company, 4041 North Richards Street, Milwaukee 12, Wis.*

**SQUARE D COMPANY**

DETROIT • MILWAUKEE • LOS ANGELES

# "What block insulation shall we use?"

# "SUPEREX, it's been our standard for over 20 Years"

Superex blocks are finished in various standard sizes and thicknesses.

• For temperatures to 1900 F, Superex is used more than any other block insulation behind refractory linings of hot blast stoves, mains, bustle pipes, kilns, regenerators, roasters, flues, stacks, industrial and metallurgical furnaces, stationary and marine boilers and auxiliary power plant equipment.

*These seven outstanding advantages have made Superex the leading block insulation:*

**1. Low Thermal Conductivity**—Superex is made from specially selected calcined diatomaceous silica, bonded with asbestos fibre—presenting a formidable barrier to the passage of heat.

**2. High Heat Resistance**—J-M Superex Blocks safely withstand temperatures up to 1900 F without deterioration.

**3. Light Weight**—Approximately 24 lbs. per cu. ft.

**4. High Physical Strength**—Withstands vibration and other physical abuse encountered in normal service. Approximately five tons pressure per square foot are required to compress Superex ⅛ inch.

**5. Permanent Efficiency**—Superex maintains high thermal efficiency indefinitely—will not disintegrate in service for which recommended.

**6. Quick Application**—The convenient sizes and light weight of Superex assure fast, economical installations.

**7. Easy Cutting and Fitting**—Superex is easily cut with an ordinary knife or saw for fitting around openings or irregular surfaces.

Special shapes or curved blocks—in addition to the 6 standard thicknesses illustrated—can be supplied. Write Johns-Manville, Box 290, New York 16, N. Y.

# JOHNS-MANVILLE *First in* INSULATIONS

**Wellman will build it**

Special Cranes
Ore Bridges
Gas Producer Plants
Charging Machines
Industrial Furnaces
Car Dumpers
Gas Flue Systems
Gas Reversing Valves
Coke Pushers
Mine Hoists
Skip Hoists
Clamshell Buckets

# Wellman Ore Bridges

***New 300 foot span!***

*Wellman 13¼ net ton ore bridge, fitted with 192 cubic foot Wellman Williams type ore bucket.*

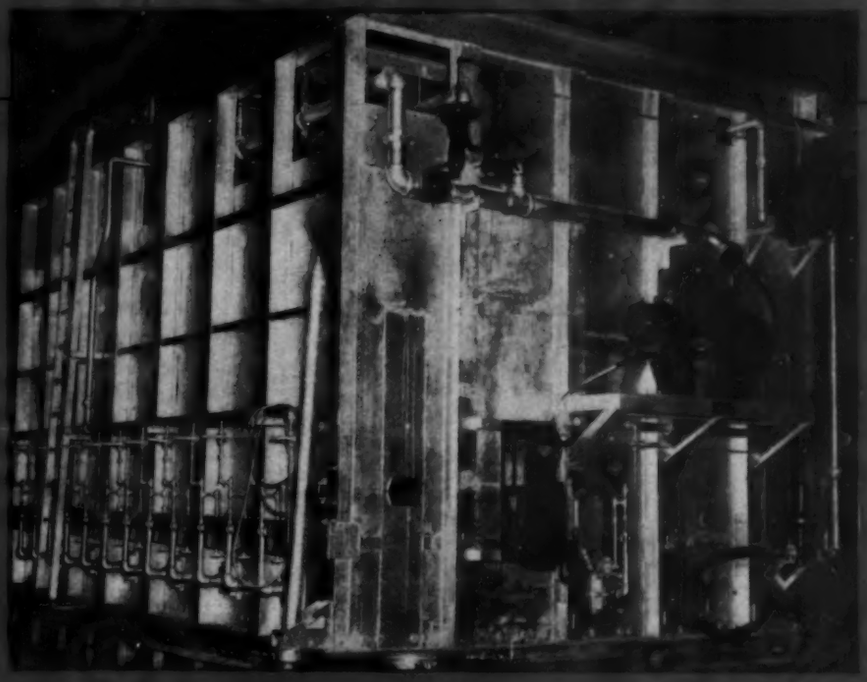
• This new installation, built for one of America's largest steel companies, embodies many engineering features which speed the handling of ore and curtail costs.

Wellman's half century of experience is at *your* service.

**THE WELLMAN ENGINEERING COMPANY**

**7031 CENTRAL AVENUE • CLEVELAND 4, OHIO**

*when it comes to perfect heat treating*



**F.E.I.**

**gets results**

F.E.I.

# F. E. I. BUILDS

**For Blooming, Plate & Rolling Mills.**

Soaking Pits for all fuels.
Continuous Bloom, Billet and Slab Heating Furnaces.

***Furnaces Equipped with F. E. I. Patented Combustion System.***

**For Wire, Bar or Tube Mills.**

Galvanizing, Patenting or Normalizing Furnaces
Cover Furnaces for bright annealing, heat treating, normalizing and spheroidizing of wire and rod products.

**For Pipe, Sheet or Jobbing Plants**

Hot Dip Galvanizing Furnaces
Salt Bath descaling furnaces for stainless steel sheet, bar and other products.

**Strip Mills.**

Direct fired Cover Furnaces for flat sheet and rail annealing, utilizing a patented base assembly.

**CONSULT WITH US ON YOUR SPECIAL HEATING PROBLEMS**

## FURNACE ENGINEERS, Inc.

**FOREIGN REPRESENTATIVES:**
For Canada: Salem Engineering (Canada) Ltd., Toronto, Ont.
For Europe, Asia: Salem Engineering Co., Ltd., 124 Devonshire Street, Sheffield 1, England.

1551 WEST LIBERTY AVENUE ★ PITTSBURGH, PA.

Great Care and Long Experience Go into the Pouring of Every Phoenix Roll.

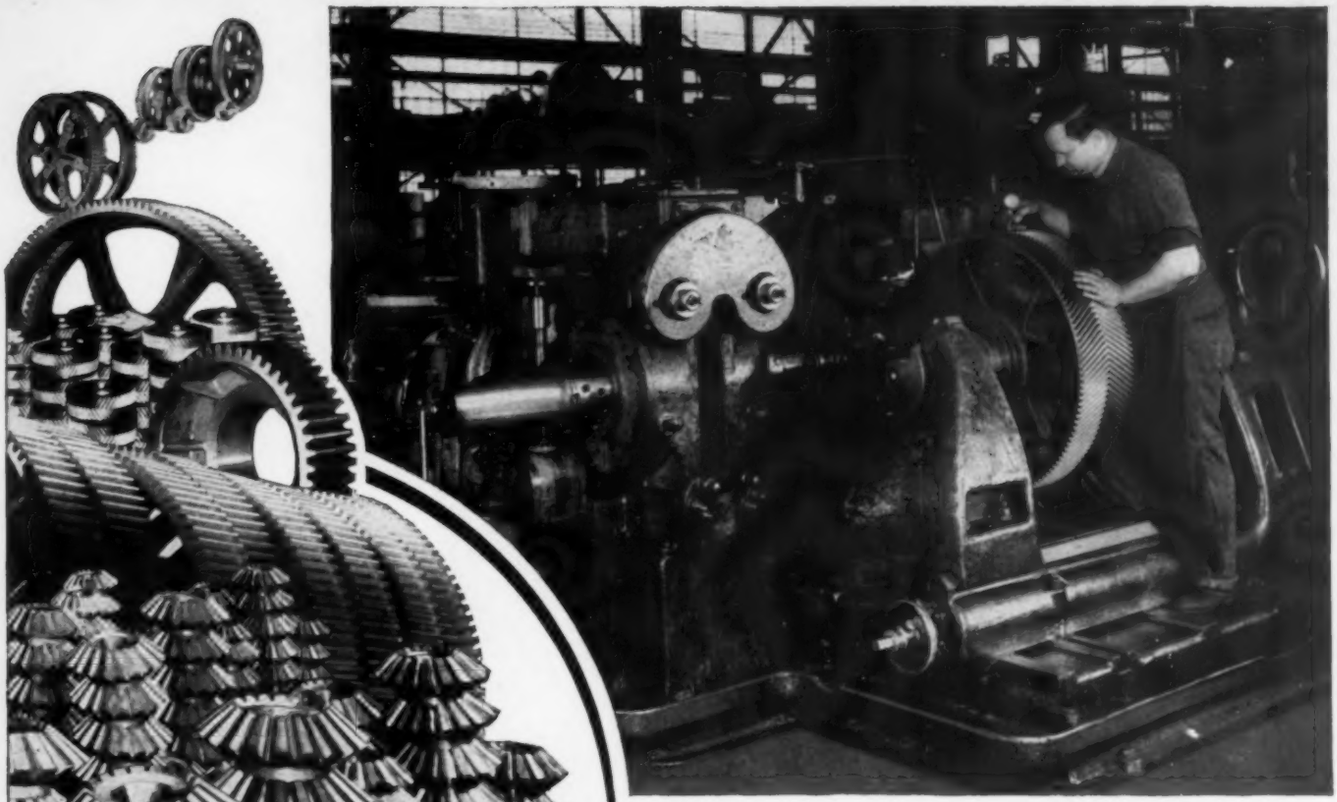
*Pittsburgh Rolls alloy iron work rolls and alloy steel back-up rolls in four-high strip mills are rolling, in addition to steel, aluminum, brass, copper, and magnesium, and are successfully producing flat rolled products at less cost per ton of steel rolled.*

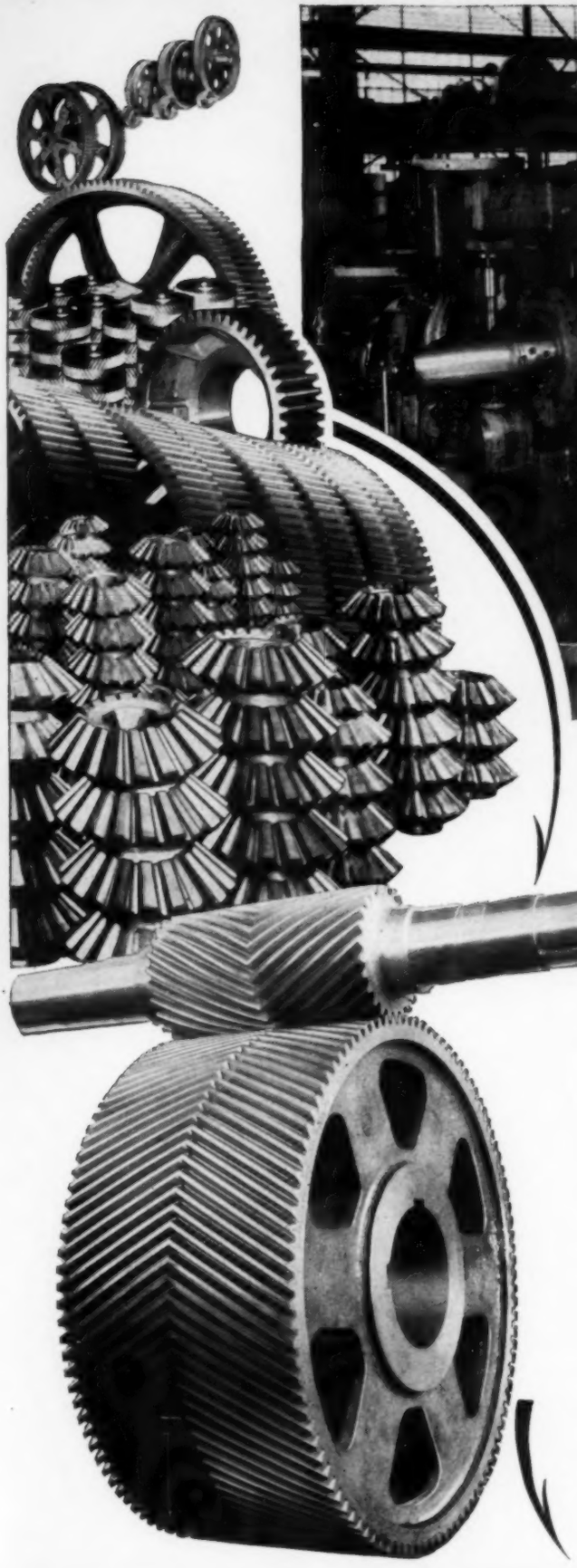
## FOUR...FIVE...SIX THOUSAND FEET PER MINUTE

As speeds go higher in continuous strip mills, roll changes and shut-downs become more costly. The durable qualities, strength, and finish of Phoenix rolls mean real savings.

# PITTSBURGH ROLLS

DIVISION OF BLAW-KNOX COMPANY, PITTSBURGH 1, PENNSYLVANIA





# GEARS

## of Neloy (OR NELOY MOLY)
## THE Preference of INDUSTRY

(NE) is the symbol of quality recognized by users of industrial gears everywhere. Our Foundries specialize in Gear Blank Castings of Alloy and Carbon Steel. The facilities of the National-Erie Corporation at your command, permit complete control from raw material to the finish machined gears. Spur, bevel and Sykes Herringbone of Neloy (or Neloy Moly) meet with outstanding success in industry because they are giving excellent service in many varied applications.

First and final costs of Neloy (or Neloy Moly) gears are reasonable. The (NE) Flame Hardening Process combines the high surface hardness of carburized or case hardened treatment, combined with the toughness of a fully quenched medium carbon alloy steel.

Neloy (or Neloy Moly) is the Ideal alloy steel for gears . . . the Preference of Industry. Let us help you meet your gear requirements.

Write for bulletin No. 7.

**NATIONAL ERIE CORPORATION**

ERIE, PENNSYLVANIA • U. S. A.

# ...for CLOSE SPOTTING and CONTROLLED DECELERATION... *Hydraulic Brakes* ARE BEST!

## —only Wagner Hydraulic Crane-Bridge Brakes give you these features:

- **Two Types—Four Sizes—Cover the Field**

  Wagner hydraulic brakes for overhead traveling cranes and other industrial equipment are built with or without parking attachment, in four sizes that are capable of handling all bridge brake applications—light industrial cranes, high speed steel mill cranes, even the largest steel mill ladle cranes.

- **Remote Control Bleeder**

  Makes bleeding the hydraulic system a "one-man one-minute" job. Keeps lines full of fluid, maintains peak braking efficiency . . . solves problem of ladle crane applications.

- **Self-Centering Device**

  Assures equal clearance of *both* brake shoes, prevents either shoe from dragging. Other advantages include: power failure braking . . . one-point shoe adjustment . . . 200% emergency torque . . . grease fittings for lubrication . . . non-scoring molded lining blocks which can be easily replaced when worn.

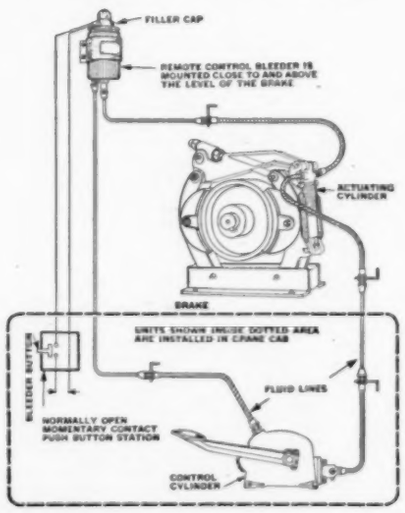
- **Modern Systems Easily Installed**

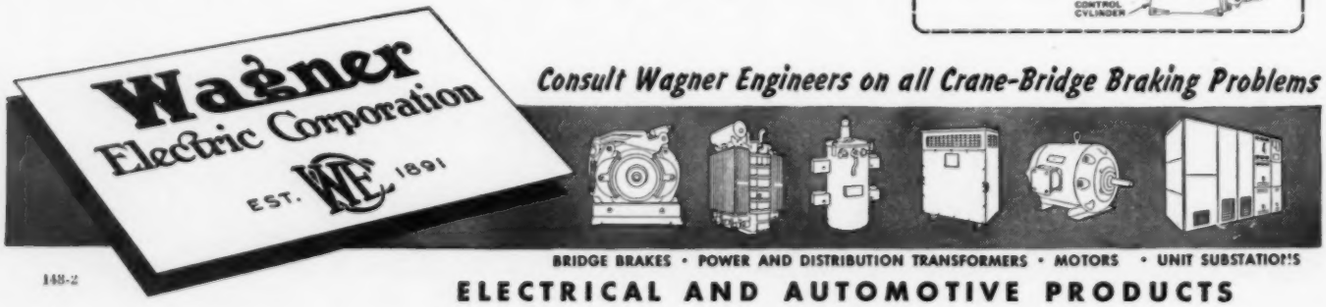
  If your cranes are not equipped with Wagner hydraulic brakes, let one of our field engineers show you how simple it is to install the modern system you need. All Wagner systems now include the remote control bleeder.

- **Old Systems Quickly Modernized**

  You can bring your present Wagner system up-to-date with our complete-to-the-last-fitting conversion kits. You can change your old solenoid-controlled HM brake to the new, compact hydraulic-released type; you can convert a type H brake to an HM; and you can easily add the remote control bleeder to any Wagner system. Write for Bulletin IU-40 on Wagner Industrial Brakes.

**Wagner Electric Corporation**
6483 PLYMOUTH AVE., ST. LOUIS 14, MO., U. S. A.


FILLER CAP
REMOTE CONTROL BLEEDER IS MOUNTED CLOSE TO AND ABOVE THE LEVEL OF THE BRAKE
ACTUATING CYLINDER
BRAKE
UNITS SHOWN INSIDE DOTTED AREA ARE INSTALLED IN CRANE CAB
BLEEDER BUTTON
FLUID LINES
NORMALLY OPEN MOMENTARY CONTACT PUSH BUTTON STATION
CONTROL CYLINDER




*Consult Wagner Engineers on all Crane-Bridge Braking Problems*

BRIDGE BRAKES • POWER AND DISTRIBUTION TRANSFORMERS • MOTORS • UNIT SUBSTATIONS

**ELECTRICAL AND AUTOMOTIVE PRODUCTS**

148-2

# S·T·R·E·T·C·H

## YOUR ROLLING MILL PROFITS!

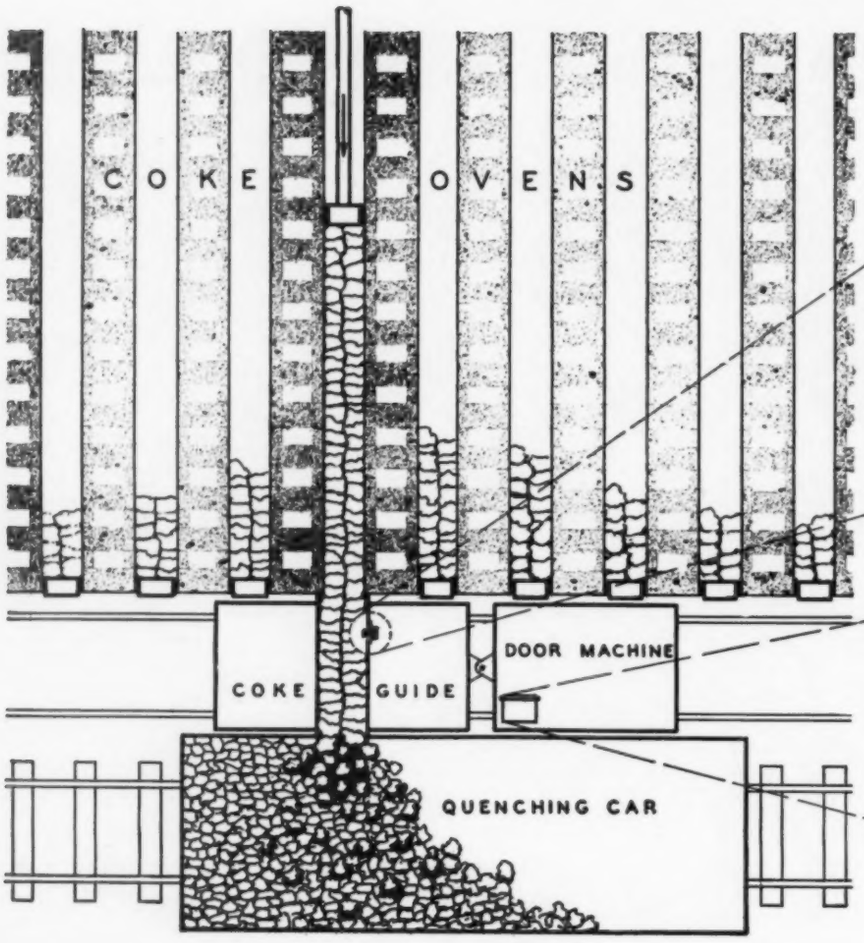
*It can be done!* Specify the rolls that have demonstrated their ability to turn out record tonnages—LEWIS ROLLS. Naturally, more time in the mill, less time on the lathe means greater profit on your roll investment.

**Lewis Foundry & Machine**
**Division of Blaw-Knox Company**
**Pittsburgh, Pa.**

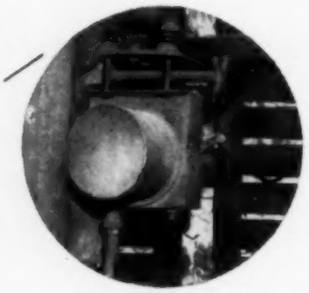
MANUFACTURERS OF
ROLLS AND ROLLING MILL MACHINERY
FOR THE IRON, STEEL AND
NON-FERROUS
INDUSTRIES

# LEWIS ROLLS

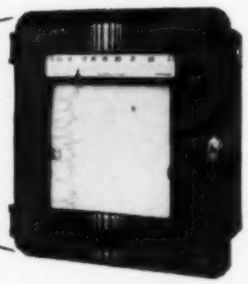
# New Way To Get COKE TEMPERATURES . . . *AUTOMATICALLY!*




**1.** Diagram shows the set-up by which Citizens' Gas & Coke Company, Indianapolis, measures temperature across the charge of coke as it is pushed from the oven.



**2.** *Rayotube* on side of coke guide detects temperature of hot coke moving past to the quench car.



**3.** *Speedomax* mounted in the cab of the oven door's operating machine continuously records temperature detected by Rayotube along the entire length of coke charge from front to back.

Coke plants can now measure coke temperatures *entirely automatically*, with a Speedomax Recording Pyrometer and Rayotube temperature detector. This equipment has proved highly successful in helping to maintain better control of oven operation — and better control of coke and by-product quality.

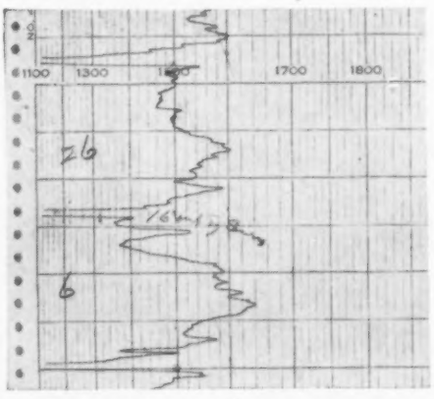
Measurements are instantaneous and complete. Because each temperature variation is recorded faithfully, the operator can tell exactly how uniformly the oven has been heated. Hot and cool spots show immediately on the chart.

By comparing records of successive loads from the same oven, operator can see the effect of changes in burner setting. This accurate information helps him bring each oven to specified temperature and uniformity.

Both Speedomax and Rayotube are entirely insensitive to vibration of the coke guide — yet they are highly sensitive to temperature. They are built to work together as a temperature-measuring team under really severe operating conditions.

An L&N engineer will be glad to discuss your problem with you, or will send Catalog N-33B. Leeds & Northrup Co., 4942 Stenton Ave., Philadelphia 44, Penna.

**4.** *Highly detailed record* drawn by Speedomax is shown below about half size. The variations shown are considered too great for ideal conditions.

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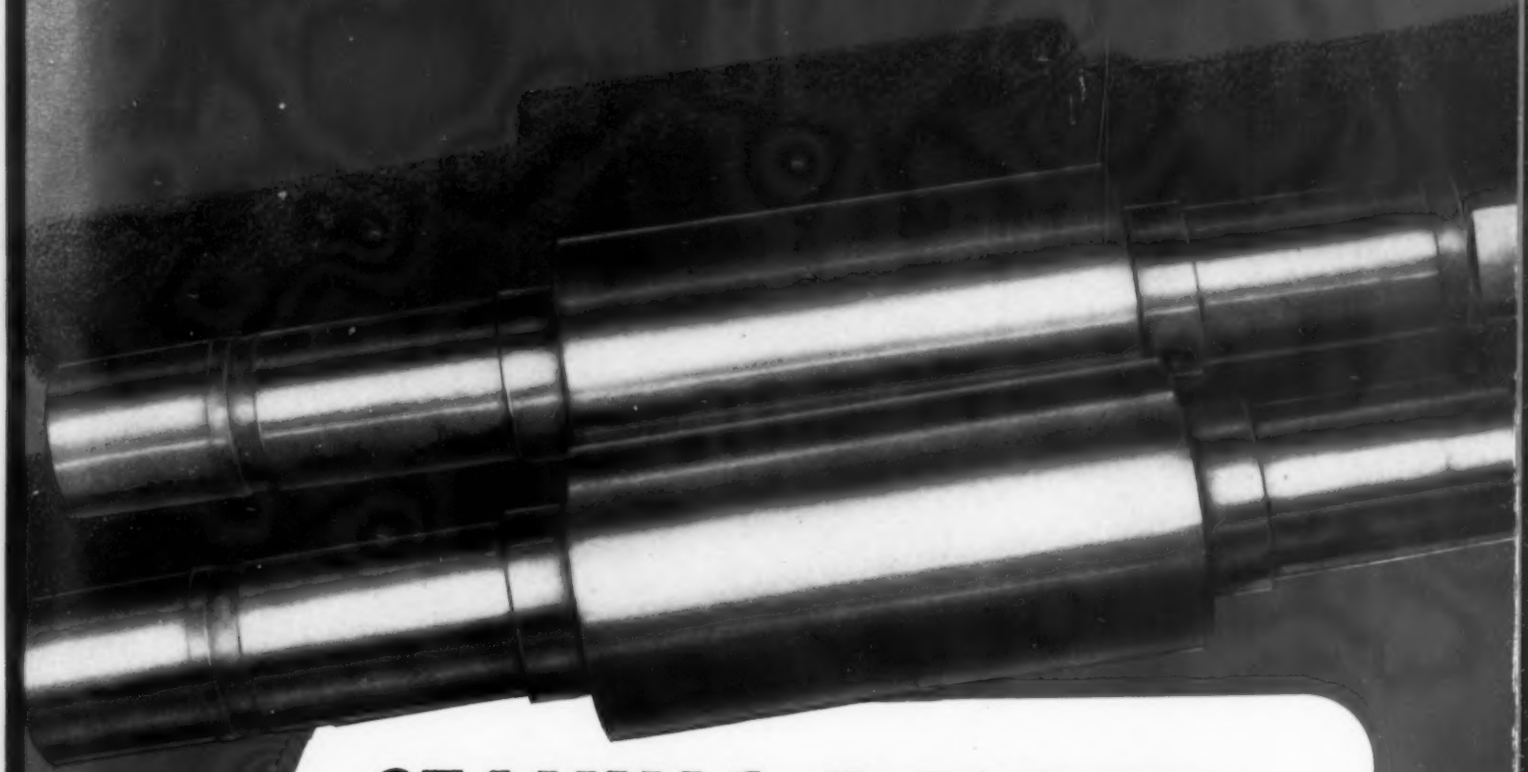
LEEDS & NORTHRUP CO.

Jrl. Ad N-33 B-705(1)

# Ohio Rolls

SHAPING METAL FOR ALL INDUSTRY



## STAYING POWER

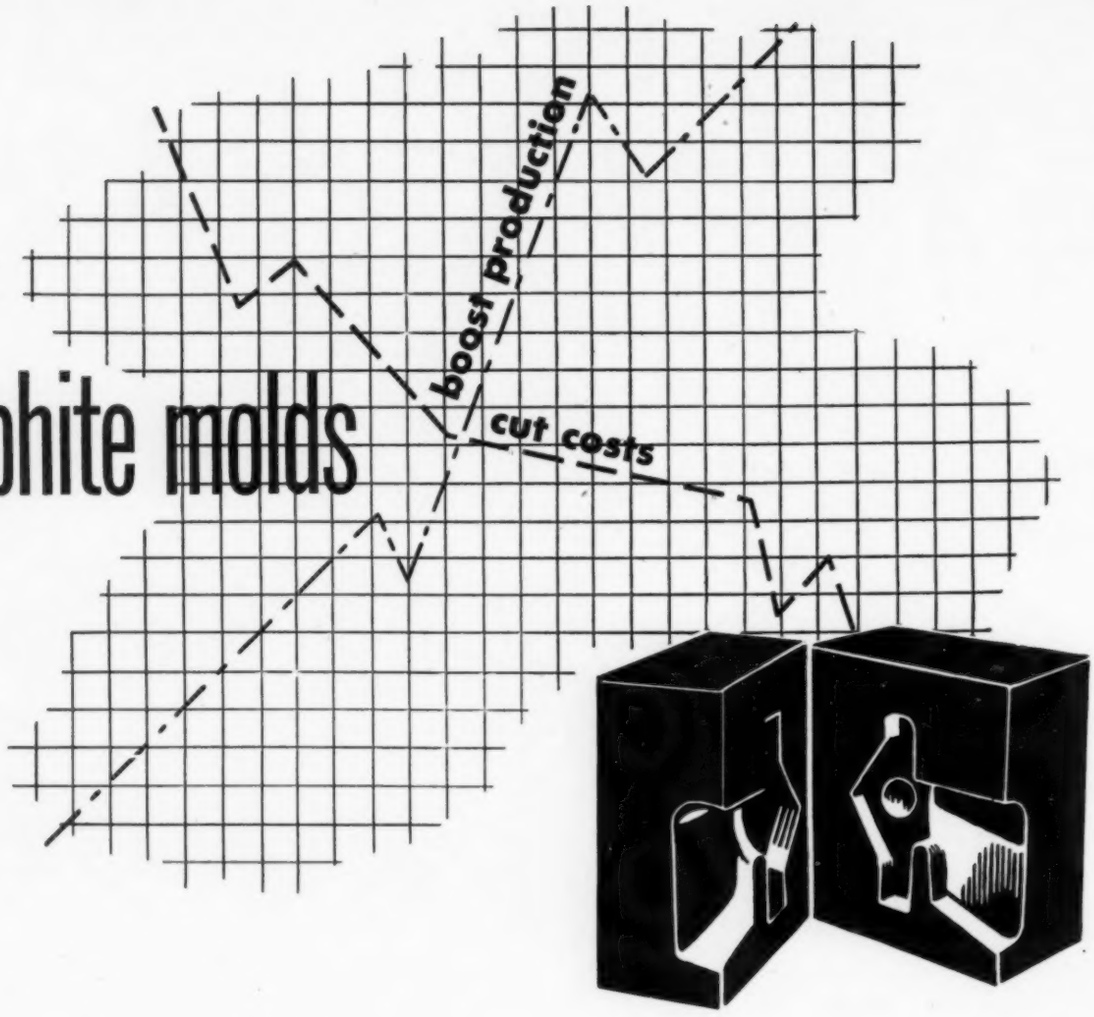
*On the job, producing longer without redressing, Ohio Rolls meet current demands for greater production in shorter time. Ohio Rolls are known for strength, wear resistance, rigidity and surface perfection.*

*Select from any of these eleven types of Ohio Steel and Iron Rolls: Carbon Steel Rolls, Ohioloy Rolls, Ohioloy "K" Rolls, HOLL-O-CAST Rolls, Chilled Iron Rolls, Alloy Chilled Iron Rolls, Denso Iron Rolls, Nickel Grain Rolls, Special Iron Rolls, Nicoloy Rolls, Flintuff Rolls.*

THE OHIO STEEL FOUNDRY COMPANY—LIMA, OHIO

PLANTS AT LIMA AND SPRINGFIELD, OHIO

# graphite molds




You get faster stripping because your castings won't stick to graphite molds. You don't need a mold wash. Graphite molds retain their physical shape even at extreme temperatures. You also get faster, more uniform cooling — and better castings.

Find out how graphite gives you greater return per dollar invested for molds. Let International's engineering staff analyze your ferrous and non-ferrous casting operations and select the right grade of graphite for you.

International supplies graphite in blocks, slabs and tubes—or machined to your blueprint specifications.

***Other International Graphite Products***

**ELECTRODES**—*for electrothermic and electrolytic use* • **MOLD PLUGS** • **GRANULAR GRAPHITE** • **GRAPHITE SPECIALTIES**

*FREE — handy booklet containing engineering data on graphite. Write today.*

## International Graphite & Electrode Corp.

ST. MARYS, PA.

3922

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**UNITED ENGINEERING AND FOUNDRY COMPANY**

**Pittsburgh, Pennsylvania**

**Plants at PITTSBURGH · VANDERGRIFT · NEW CASTLE · YOUNGSTOWN · CANTON**

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56"-4 High, 5 Stand Hot Finishing Mill. In operation in England.

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*Designers and Makers of Rolls and Rolling Mill Equipment*


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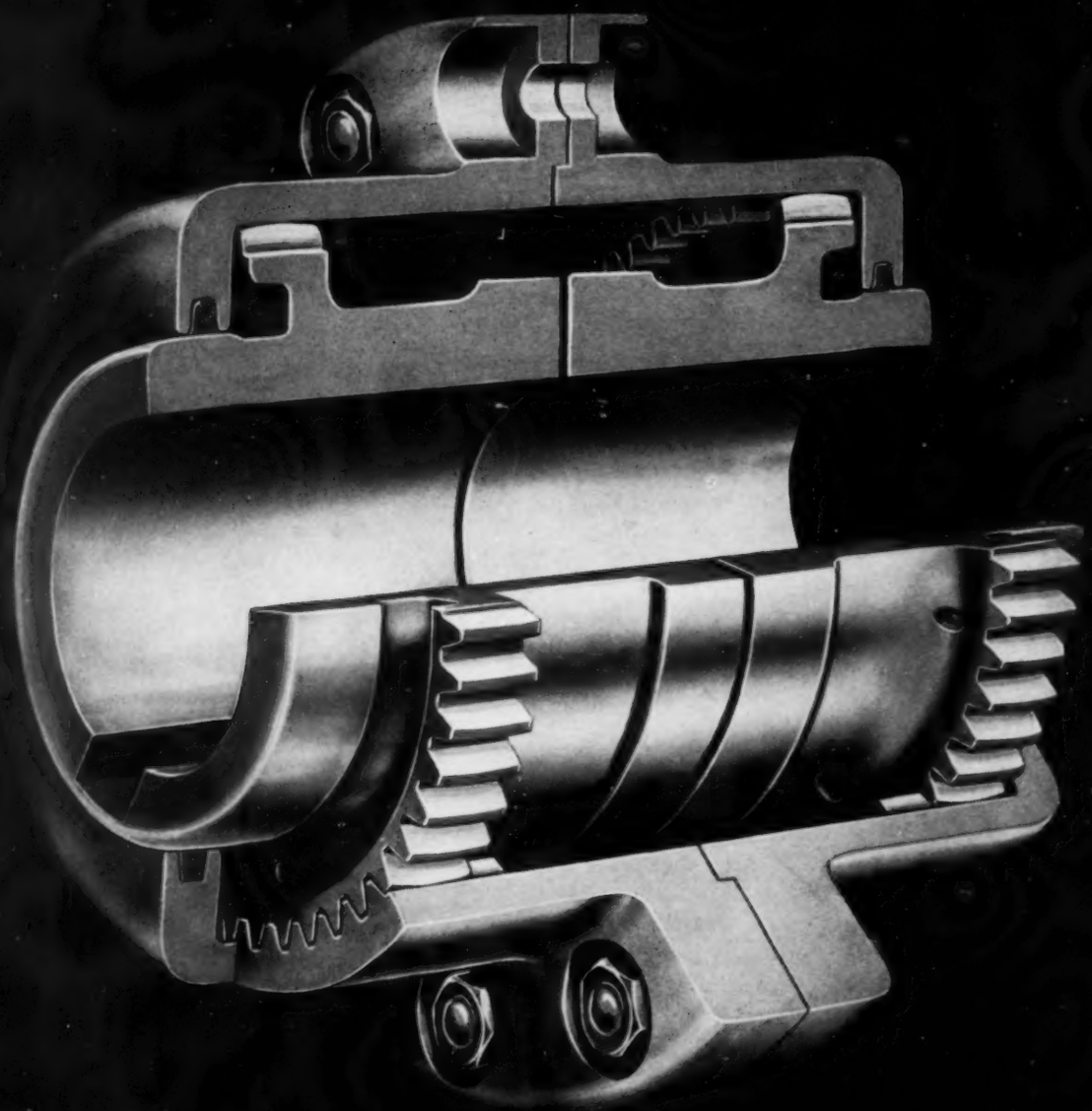
# POOLE



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# FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY

WOODBERRY, BALTIMORE, MD.

# PRODUCT Information

## ON ANY OF THE PRODUCTS MENTIONED IN THIS ISSUE

Below is an index of products referred to in editorial and advertising pages of this issue. If you desire additional information on any of them, use one of the accompanying postcards in requesting it. In each case give name of product and page number. The information will come to you directly from the manufacturer involved.

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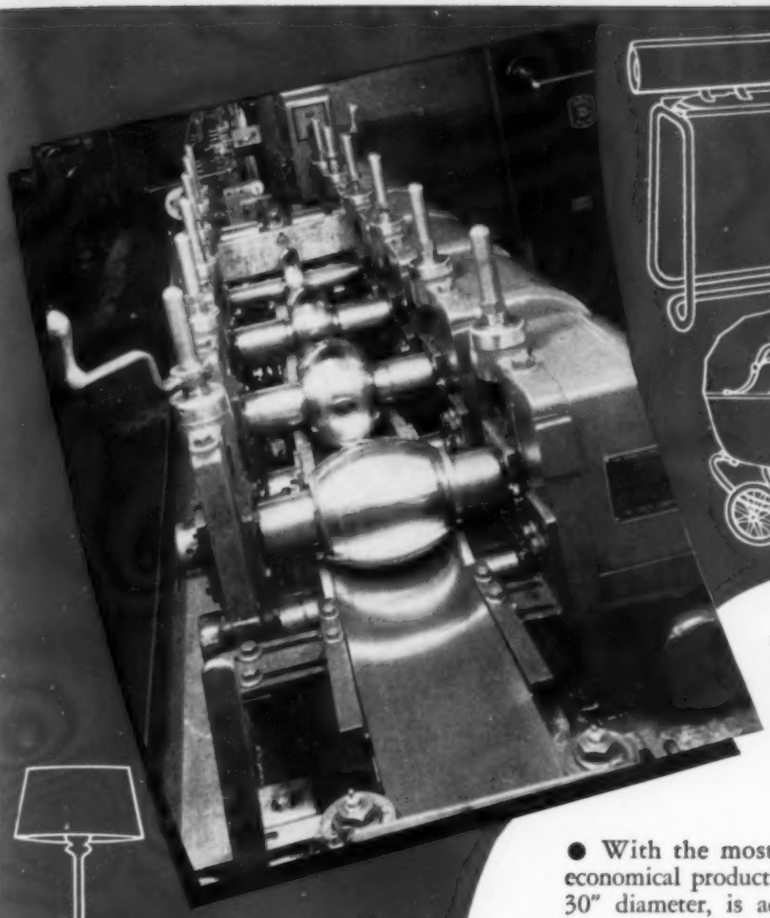

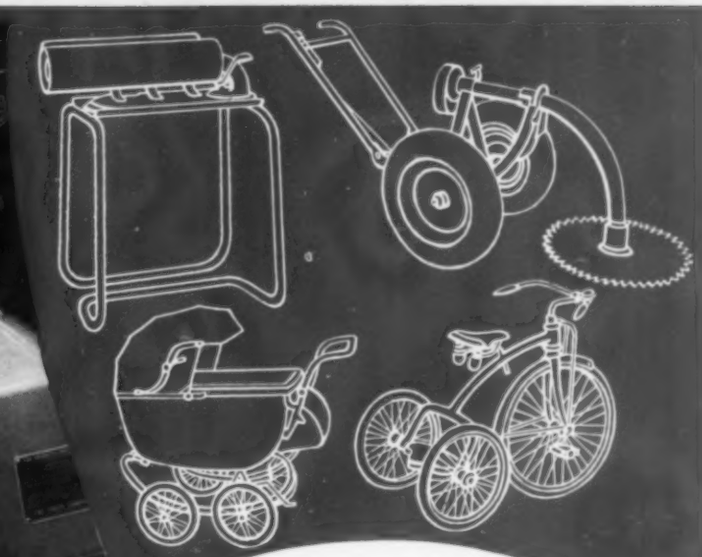

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A multiplicity of mechanical refinements, safeguards and controls have been introduced to make operation simpler, easier, more positive, more automatic and accurate than thought possible only a few years ago.

Considered from every standpoint—investment required, operating and maintenance cost, quality and quantity of output, Yoder tube mills are so outstanding that over 100 of them have been shipped, to all parts of the civilized world, since the beginning of World War II—probably twice as many as of all other tube mills combined. Not a few of them are operated by furniture, automotive and other equipment companies making tubing for their own use.

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**ROLL FORMING, TUBE MILL AND SLITTING MACHINERY**

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*"Quick on the Draw!"*

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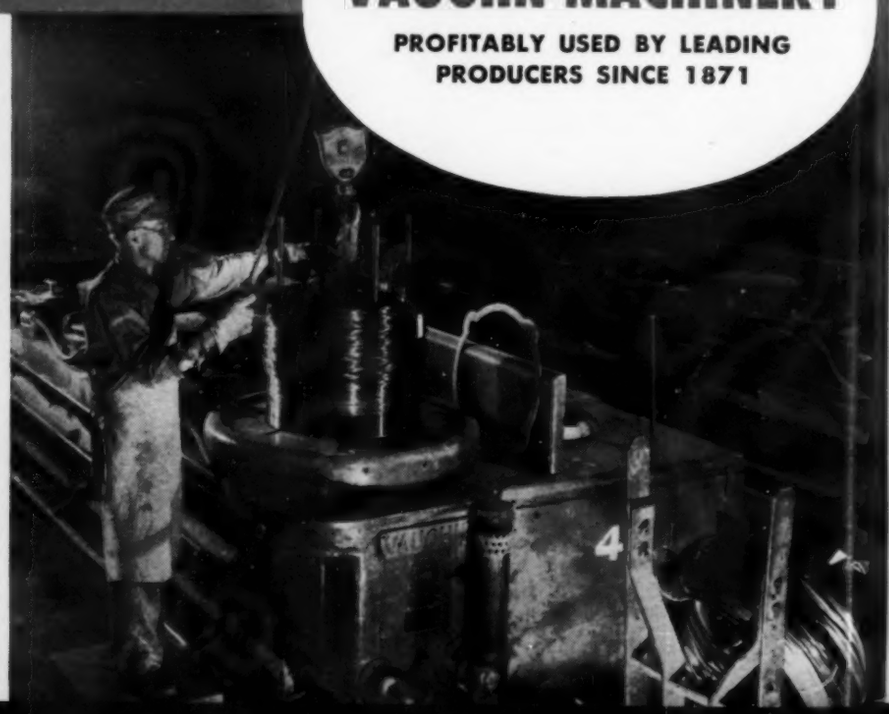
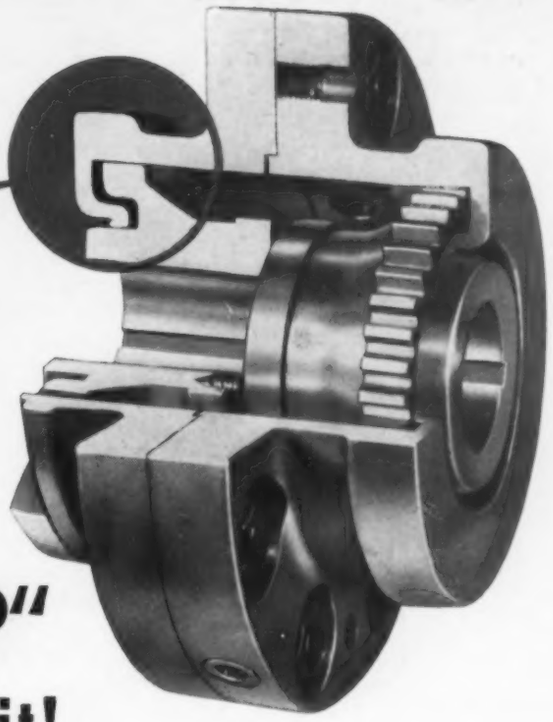




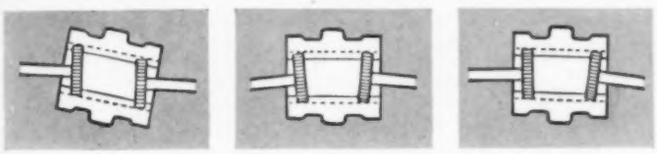
*This*

# Metal-to-Metal Seal says "STOP" to Moisture, Dust and Grit!

## That's why FAST'S COUPLINGS Give *Continuous* Service!

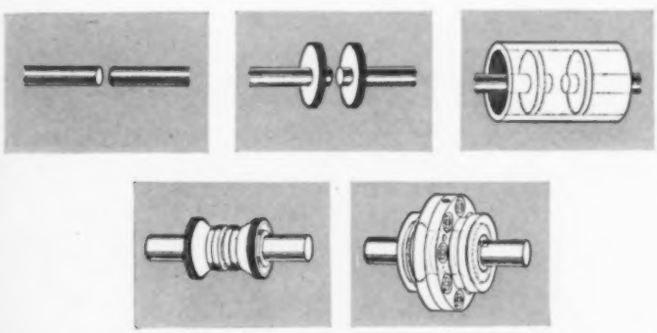
FAST'S self-aligning Couplings are completely free of perishable parts. They're all-steel throughout. At the vital spot shown above, this important feature is achieved through an *exclusive* "rocking bearing." This bearing is exclusive in providing a positive *metal-to-metal* seal that guards the load-carrying oil against troublesome moisture, dust and grit. The bearing is also exclusive in its correctly engineered position which allows *freedom of movement* to compensate for misalignment because its spherical base has the same axis as the hub spline faces. No perishable packing rings are used. There's nothing to wear, nothing to fail. Result: *uninterrupted* power transmission for all your installations!

We have a complete line of couplings for immediate delivery. No matter which type of Fast's Couplings you buy, you get the benefits of years of top engineering experience, Koppers' high standard of workmanship and unexcelled coupling service which assures you of spare parts no matter how old your couplings may be. That means longer machine life, lower upkeep costs, minimum shutdown losses! Koppers Co., Inc., Fast's Coupling Dept., 217 Scott St., Baltimore 3, Md.



### Compensate For All Misalignment

The floating sleeve takes a neutral position. All forms of misalignment are compensated for between the lubricated faces of the splines, equally divided between driving and driven members. The entire assembly revolves as one unit.



### Simple As A-B-C

Fast's self-aligning Couplings are amazingly simple for the important job they handle. A splined hub on each shaft end. A sleeve with internal splines to mesh. Oil in the sleeve, kept between the splines by centrifugal force, carries the load between the splines.

K KOPPERS

# FAST'S *self-aligning* COUPLINGS

**SEND FOR FREE CATALOG** giving detailed descriptions, engineering drawings, dimension and capacity tables and typical installation photographs for the many types of Fast's Couplings. Fill out this coupon and mail it to: Koppers Co., Inc., Fast's Coupling Dept., 217 Scott St., Baltimore 3, Md.

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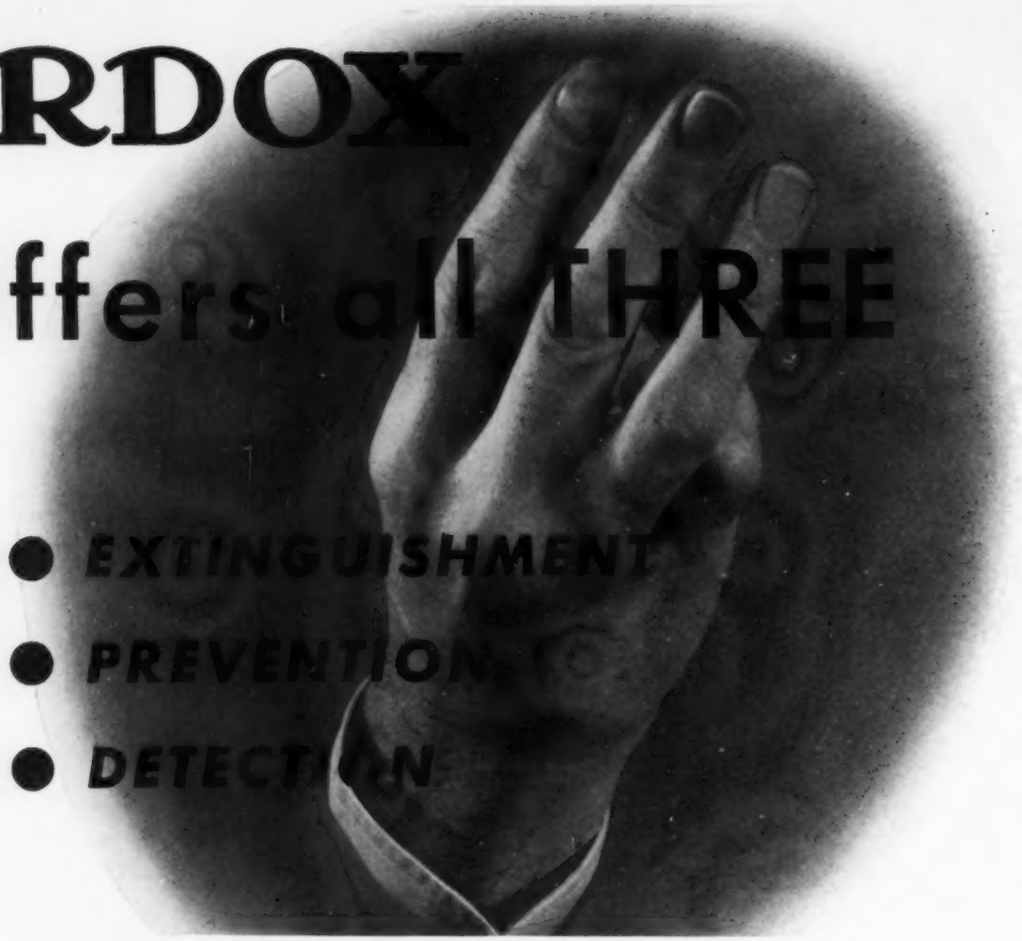
# CARDOX

## offers all THREE



- EXTINGUISHMENT
- PREVENTION
- DETECTION

How thoroughly have you analyzed your fire problems?—and how recently? Are you fully informed in all that is new in methods and equipment for improved protection of every type of fire hazard? As a leader in all three vital phases of fire protection... *Extinguishment, Prevention,* and *Detection*...Cardox offers you practical cooperation in determining the most efficient method . . . or combination of methods . . . for guarding against staggering fire losses.

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Cardox engineered applications of low-pressure carbon dioxide give this fast-acting, non-damaging extinguishing medium maximum effectiveness in conquering fires, large or small, both indoors and out. Cardox Fire Extinguishing Systems offer broadscale protection with centrally located, compactly designed storage units with capacities of 500 pounds to 125 tons of Cardox $CO_2$, and Mobile Units with capacities of 750 pounds to 3 tons. Bulletin S-478.

### PREVENTION

Cardox Atmosphere Inerting Systems are available to provide inert gas for *continuous* fire and explosion prevention in the handling and storage of flammable liquids, chemicals, paints, varnishes, and solvents, or where other materials in storage present serious fire and explosion hazards. These systems also are used to provide an economical source of inert gas as part of continuous production processes.

Bulletin C-478.

### DETECTION

Cardox Detection Systems, actuated by heat, smoke or flame, give prompt warning of incipient fires. These systems, with detectors located throughout large establishments . . . may be used purely as a warning device, or may be engineered to actuate an extinguishing system.

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VULCANIZING IN A METAL MOLD GIVES *Longest-Lived* CABLES

...but only Okonite uses this process as standard practice

with today's installation costs* only the *Longest-Lived* will be economical

* The lifetime cost of a cable rather than its first cost is the only true measure. Okonite wires and cables, built to stand up better and longer, can offset high installation costs.

6511

When Okonite insulated wires and cables are vulcanized, every foot that enters the huge pressure chamber receives uniform treatment. One reason is this:— on the reel or drum as it goes into the vulcanizer, the complete length of cable is compressed within a *continuous metal mold.* And this metal mold insures equal transfer of the heat throughout every portion of the insulation.

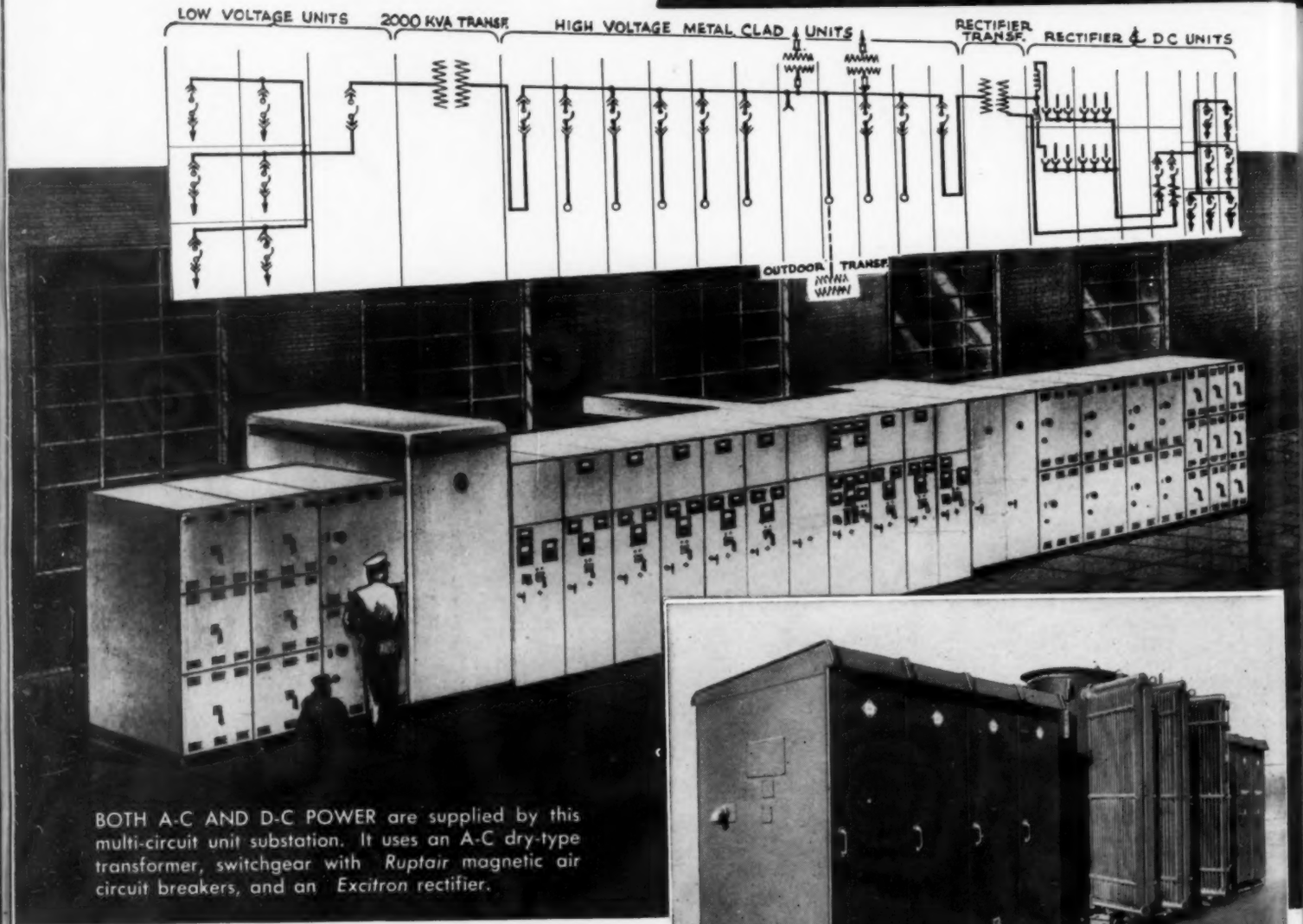
When the pure tin mold is peeled off after removing the cable from the chamber, the entire length has been simultaneously vulcanized at the same temperature and pressure. *The benefits that result include longer life, greater density and higher electrical values.*

Bulletin 1S-101 describes and shows this operation and others — all based on Okonite's years of experience in making the longest-lived cable money can buy. Write to The Okonite Company, Passaic, N. J.

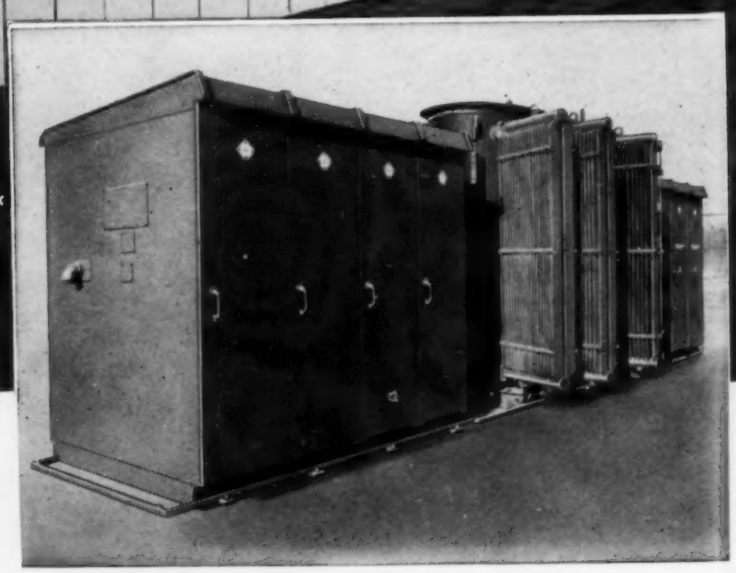
OKONITE SINCE 1878 insulated wires and cables

THE BEST CABLE IS YOUR BEST POLICY

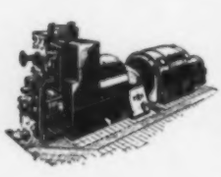
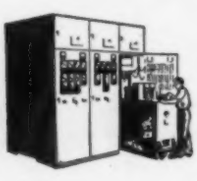
# LOAD CENTER LOWER

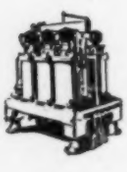
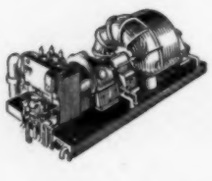
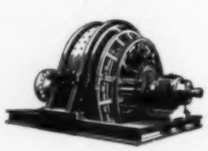



BOTH A-C AND D-C POWER are supplied by this multi-circuit unit substation. It uses an A-C dry-type transformer, switchgear with *Ruptair* magnetic air circuit breakers, and an *Excitron* rectifier.



**TYPE MCS** MULTI-CIRCUIT UNIT SUBSTATION. Consists of two or more vertical-lift metal-clad switchgear units throat-connected to a power transformer. Size is limited only by switchgear—500,000 kva maximum interrupting capacity. Either outdoor or indoor design is used depending on load and space requirements. It may be installed centrally to supply its rated load or to feed other smaller substations at selected load centers.

**POWER & ELECTRICAL — Steam Turbines, Condensers, Water Conditioning, Power Transformers, Switchgear, Unit Substations, Circuit Breakers...**

**UTILIZATION & PROCESS — Motors, Blowers, Rectifiers, M-G Sets, Betatron, Pumps, Compressors, *Regulex* Exciters, *Texrope* V-Belt Drives . . .**

# POWER... COST STEEL!

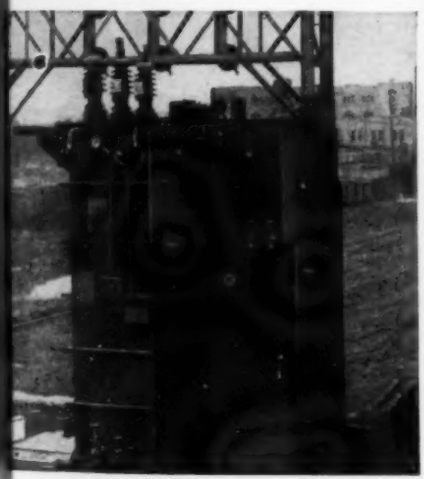
## Load Center Mill Power Distribution with Allis-Chalmers Unit Substations Saves Money . . . Has Expansion Flexibility . . . Improves Voltage Regulation and Cuts Line Losses!

IRON AND STEEL PRODUCERS can cut production costs by using the load center system of power distribution with Allis-Chalmers modern unit substations. These space-saving units bring *rated* voltages to plant equipment for *increased efficiency, lowered maintenance costs,* and *less outage time.* Easily maintained and installed, unit substations cut cost and size of copper. They provide *flexibility* of power distribution . . . expansion or relocation is no problem.

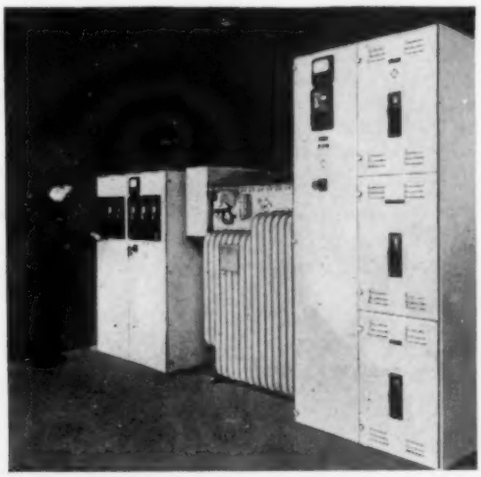
Metal enclosed throughout, they assure *maximum* safety for personnel, both during daily plant activity and during inspection or maintenance operations.

Load requirements determine which of the four types to use . . . or the best combination for overall mill power distribution. They can be built for indoor or outdoor service . . . with dry-type, oil-filled, or Chlorextol-liquid-filled power transformers as desired. Standardization of design permits forecasting of space needs and handling operations.

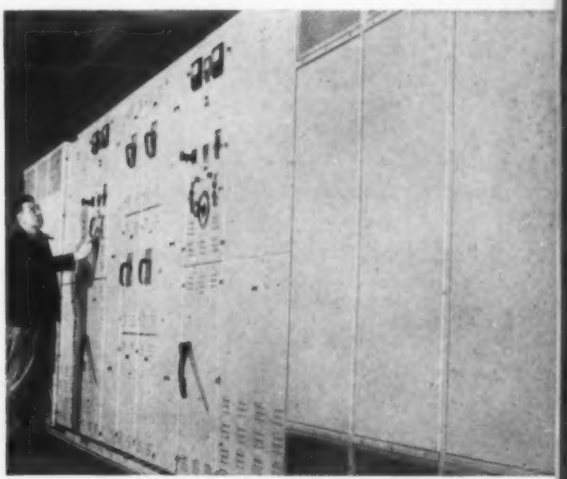
Your nearby A-C office will provide further details, or write ALLIS-CHALMERS, MILWAUKEE 1, WIS.



**TYPE SCS** SINGLE-CIRCUIT UNIT SUBSTATION has power transformer and control equipment for a single feeder supply in a compact unit housing. It can be used as a permanent substation or as a temporary power source for isolated, concentrated loads or loads whose location is shifted at intervals.



**TYPE LCS** LOAD-CENTER UNIT SUBSTATION provides a 600-volt or lower power source for auxiliary motor and lighting loads. Its compact construction cuts space needs with roof or balcony mounting possible. Lines enter through units ranging from plain junction boxes to metal-clad switchgear. Feeder circuits are controlled by dead-front air circuit breaker switchgear.



**D-C** LOAD CENTER UNIT SUB uses factory-assembled and wired, sealed *Excitron* rectifier with normal a-c L-C sub equipment. This combination is highly efficient source of 250-volt d-c power at the load center. Shortens heavy copper runs, simplifies installation.

A 2494

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**One of the Big 3 in Electric Power Equipment—Biggest of All in Range of Industrial Products**

*A view showing a portion of ten new 'Surface' Annealing Covers and 22 Bases with Coil Separators, High Powered Base Fans, and Deep Corrugated Alloy Inner Covers, at Irvin Works, Carnegie-Illinois Steel Corporation.*

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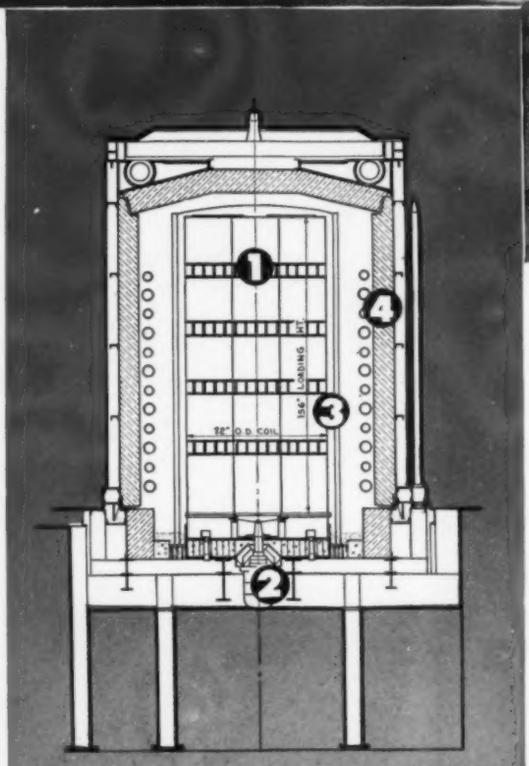
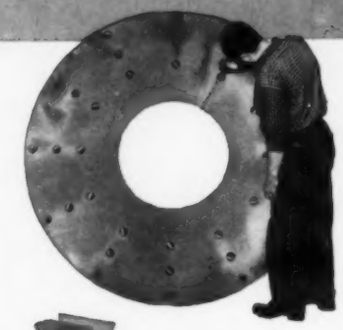


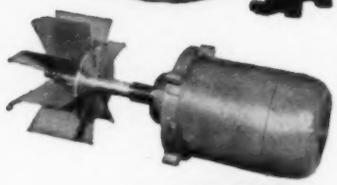

*Cross section drawing of the 'Surface' Balanced Heat Flow System with the elements in working position.*

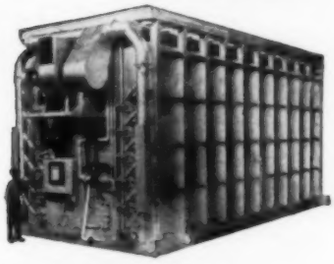
**SURFACE COMBUSTION CORPORATION • TOLEDO 1, OHIO**

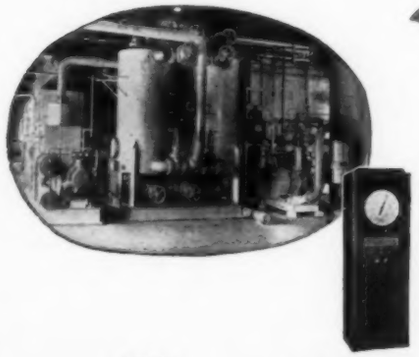
# *Balanced* HEAT FLOW

## ANNEALS COILS FASTER AND BETTER









★ **Four new 'Surface' developments and improvements, used together in a balanced heat transfer system, are breaking records for speed and uniformity in strip coil annealing.**

1. **COIL SEPARATOR** ● Of simple, rugged construction for balanced convection heating and cooling. Directs rapidly circulated heating and cooling gases to the ends of the coil laminations thereby utilizing solid metal heat transfer, rather than conduction through laminations.

2. **HIGH POWERED BASE FAN** ● 'Surface' design. Power input ten times greater than used formerly. Incorporates a unique method of sealing annealing atmospheres against differential pressures.

3. **CORRUGATED INNER COVER** ● Deep corrugations absorb and transfer the heat to the circulated gases within the inner cover during the heating cycle and speed cooling of the charge by reason of the large area exposed.

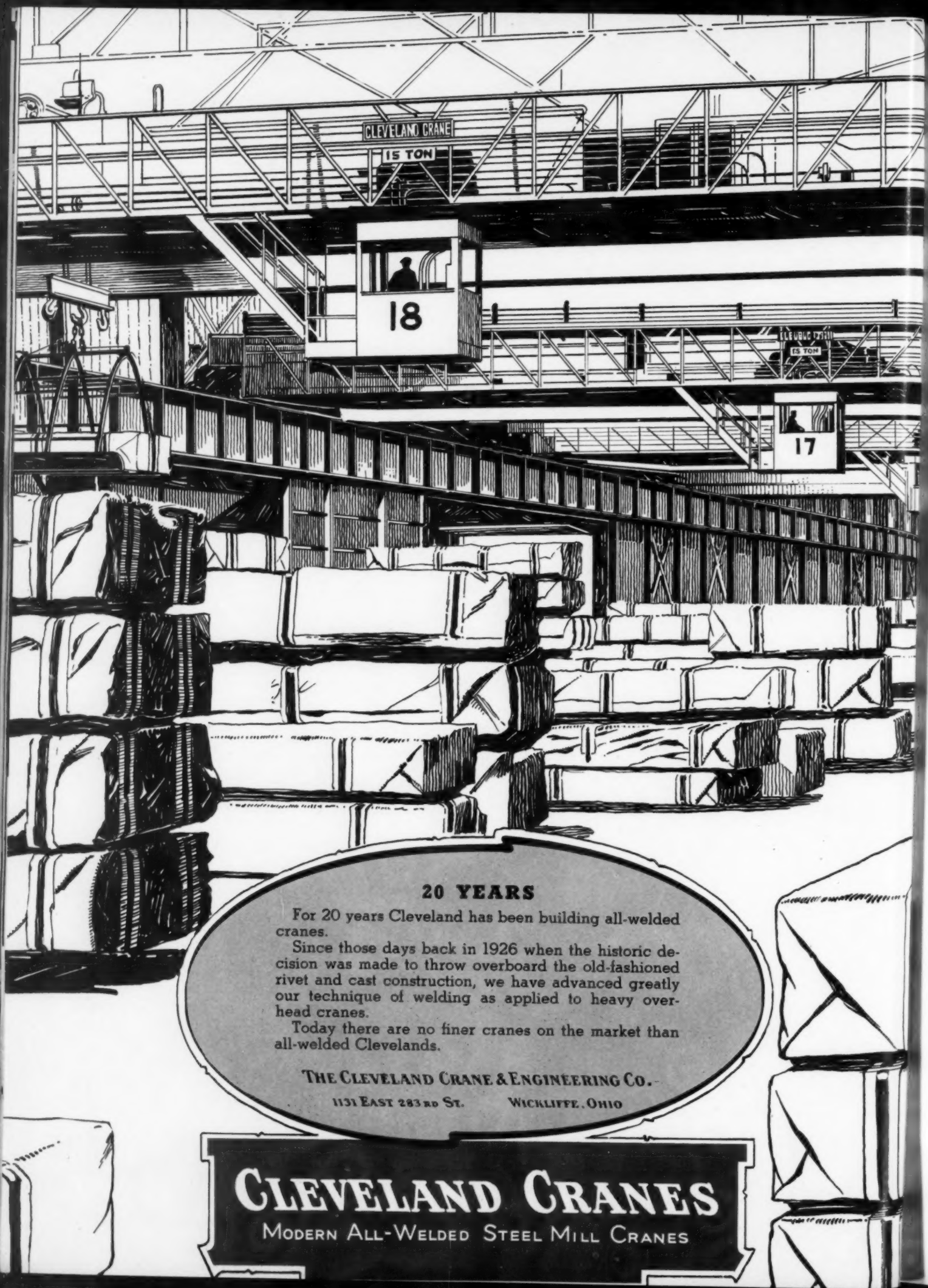
4. **RADIANT TUBE HEATING COVER** ● Stepped-up useful heat input of 'Surface' Radiant Tubes balances the fast heat absorption rate of the new deep-corrugated inner covers and fast heat transfer of base fans and coil separators.

**Two additional 'Surface' developments assure 'Quality Control' of heat treated products.**

5. **NX ANNEALING ATMOSPHERE GENERATOR** ● Furnishes a gas atmosphere environment for the steel, producing the highest quality electrolytic tin plate. Tin plate annealed in 'Surface' NX Gas Atmosphere shows higher corrosion resistance, more uniform plating, and fewer plating defects.

6. **DEW POINT RECORDER** ● Provides a constant reference of water content of the atmosphere annealing gas, and when used with an "atmosphere selector" the gases from as many as six different furnaces can be analyzed at predetermined intervals.

# *'Surface'* COIL ANNEALERS

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For 20 years Cleveland has been building all-welded cranes.

Since those days back in 1926 when the historic decision was made to throw overboard the old-fashioned rivet and cast construction, we have advanced greatly our technique of welding as applied to heavy overhead cranes.

Today there are no finer cranes on the market than all-welded Clevelands.

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MODERN ALL-WELDED STEEL MILL CRANES

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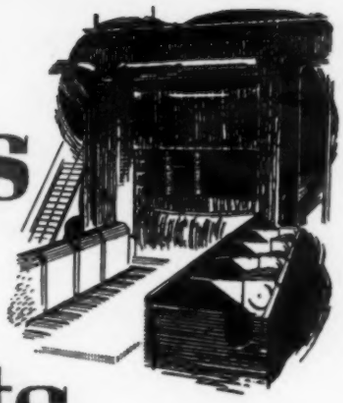


EVERY so often one or another of the technical groups serving the steel industry becomes aggrieved because it believes that the work of some other group is infringing on the territory which has been staked out for themselves. Occasionally these disputes border on the ludicrous. In the steel industry, the various departments and branches of engineering are so inter-related that precise lines of demarcation are impossible.

We believe that the only reason for the existence of the various technical groups is the service they render to the profession or industry they cover, by developing their members into better men and by helping to improve methods and processes in their industry. No one group can afford the arrogant conceit of thinking it is doing, or can do, the entire job alone. The time spent in jurisdictional disputes (so universally decried in the labor field) might better be spent in making sure that each society is doing the best job they can to benefit their industry.

▲

AUTHORITIES say that enough gasoline and oil to meet the nation's requirements for 1500 years can be manufactured from only one-quarter of our known coal reserves

▲

A PSYCHOLOGIST says that girls prefer jobs where they take orders rather than give them. Just goes to show how marriage changes people.

▲

DIVIDENDS paid by the United States Steel Corporation in 1947 — that year in which profits were called excessive by many unthinking people — averaged $4.84 per week per worker. At 40 hours a week, that is 12.1¢ per hour. There's no room there for a wage increase.

▲

STATISTICS from the U. S. Department of Labor show that the cost of living has risen 69.3 per cent from 1939 to 1947. During the same period, wage rates in all lines of manufacturing have gone up 92.9 per cent. The weekly pay check will now buy 22 per cent more goods than it would eight years ago.

▲

A CLASSIFIED advertisement in the New York Times, Help Wanted, Female: "Secretary with intelligence, personality and at least three years legal experience for interesting post close to a boss full of ideas."

TRAINING of employees now occupies a spot of top interest for almost every major steel producer. Old plans are being broadened, new plans are being set up. When the effects of these activities begin to be felt, the companies will face the problem of moving the trained men along so as to retain them and keep them happy.

▲

STEEL distribution in 1947 followed the following pattern:

| | Per cent |
|---|---|
| Automotive | 16.3 |
| Construction and maintenance | 16.0 |
| Railroad | 9.6 |
| Machinery and tools | 9.2 |
| Containers | 8.9 |
| Exports | 7.3 |
| Pressing, forming and stamping | 6.0 |
| Oil, gas, water and mining | 5.9 |
| Agricultural implements | 3.8 |
| All others | 17.0 |

Export figures show 6,543,085 tons (10.4 per cent) of finished steel sent to other countries during 1947, a peace-time record.

▲

APPROVAL by the U. S. Supreme Court of the purchase of Consolidated by Columbia can bring little comfort to business men in their consideration of future plans. The 5–4 vote of the court leaves slim margin of one man's opinion between the widely divergent views of legitimate business expansion and transgression of anti-trust laws.

▲

OVERALL construction costs for steel plants are now 80 per cent higher than in 1940.

▲

SOME wonderful examples of government by the people: the repeal of taxes on oleomargarine, favored by perhaps 80 per cent of the population, is stymied by a handful of the people's elected representatives. (Incidentally, oleo production now approximately equals that of butter.) And now some of the same people's representatives want to spend good money to investigate effects of tobacco on the soil in which it is raised, on the workers in the industry, and on the users, as well as the sales and advertising practices of the tobacco manufacturers. It's a wonderful thing, democracy.

▲

MANY persons might have attained wisdom had they not assumed they already possessed it.

▲

JAMES F. LINCOLN, president of the Lincoln Electric Company, states that a fundamental mistake in labor-management relations is the practice of paying workers for their presence in the plant rather than for the work he does. He says the government should support incentive management, keep bureaucracy from interfering with incentive plans, eliminate the power of union leaders to call strikes against the will of union members, provide an incentive tax program, and refrain from forcing an employee into a union where he is one of a flock without hope of advancement or pride in his individuality.

▲

WHAT with everybody going to the seashore, it might be well to remember that a month on the sands often ends up with eleven months on the rocks.

# *Resistor* FAILURES COST MONEY!

LOST MACHINE TIME...

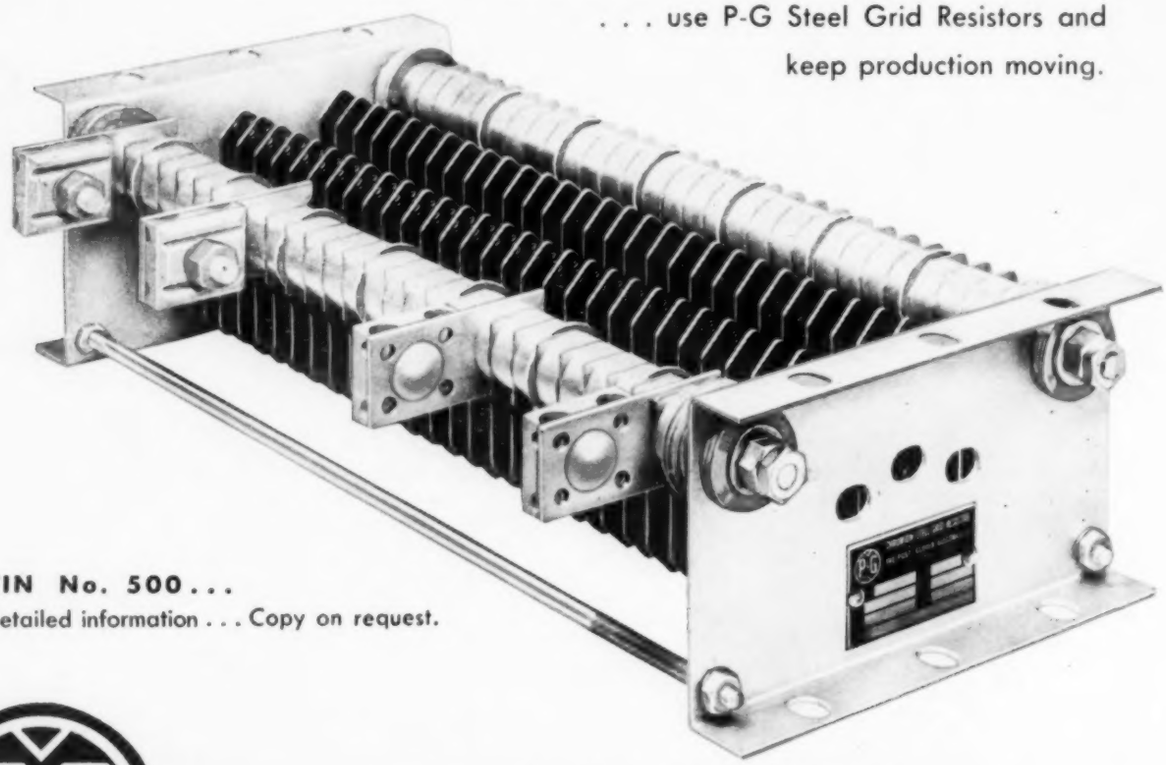
DAMAGE TO MOTORS...

DAMAGE TO CONTROLS...

COST OF NEW RESISTORS...

## P-G *Steel Grid Resistors* REDUCE THIS COST . . .

Steel and mica construction with provision for expansion, enable P-G Resistors to withstand many factors frequently causing resistor failure. By fewer failures, P-G Resistors minimize the effect of lost machine time and expensive electrical maintenance. Be protected . . . use P-G Steel Grid Resistors and keep production moving.



**BULLETIN No. 500...**
Gives detailed information . . . Copy on request.

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*The Nonbreakable Steel Grid Resistor*

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•
FORGINGS AND RINGS

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PITTSBURGH 30, PENNA.

# Operation and Maintenance of Automatic Preset Plate Mill Screwdown Control

*. . . . automatic preset screwdown control gives a more uniform gage plate . . . . it should thus improve yield . . . .*

## ELECTRICAL FEATURES

By JOSEPH F. SKALKA, General Foreman
120 in. Mill Electrical Maintenance
Lukens Steel Company
Coatesville, Pennsylvania

▲ THIS paper will discuss the operation of the automatic preset screwdown control of our 120 in. plate mill. *Preset* means that a sequence of roll openings can be set up for a series of passes, so that by merely pressing a button, once after each pass, the roll opening is automatically adjusted for the next pass. Presetting is accomplished by means of a plug board.

Figure 1 is a general view of our 120 in. finishing mill. On the left is the control pulpit where the operator is sitting at the control desk. Behind him is the plug board and control mechanism. Here there is a dial for double check, facing the operator. Vertical rolls for trueing the plate edges, and side guards for alining the plates appear in the foreground. They operate automatically with the screws, according to the width of plate being rolled.

The selsyn transmitter which synchronizes the control mechanism in the pulpit, with the motion of the screws, is hidden behind its gear guard.

Figure 2 shows the interior of the pulpit. There is a row of lamps on the left, which signal the number of the pass for which the mill is adjusted. Next is a line of productimeters which indicate in inches the positions of the rolls, side-guards and edgers. The button which starts the automatic adjustment for the next pass is plainly visible immediately in front of the operator. Either of two schedules is available to the operator at the turn of a switch. In this picture the operator's assistant is preseting the schedule not then in use. The plugs and cords used in preseting are plainly visible here. Of the automatic control mechanism, only the selsyn receiver is visible.

Figure 3 is a closeup of the preset plug-board. The receptacles on the left are available for both schedules. Each row of four receptacles is permanently connected to a point on a potentiometer, and accounts for $\frac{3}{8}$ in. of roll opening. The receptacles on the right are connected to a point on a second potentiometer which acts as a vernier to make possible presets to $\frac{1}{80}$ in.

The small groups, each of one plug and cord and a few receptacles, enables preset for automatic return to first pass conditions after any odd pass from 5 to 21, inclusive.

The three small relays control operation of the side-

Presented before AISE Philadelphia District Section Meeting, April 5, 1947.

**Figure 1 — Newest of the rolling facilities at the Lukens Steel Company is the 120 in. plate mill, which was placed in operation late in 1943.**

**Figure 2 — All control buttons and dials are located so that they are convenient to the operator.**

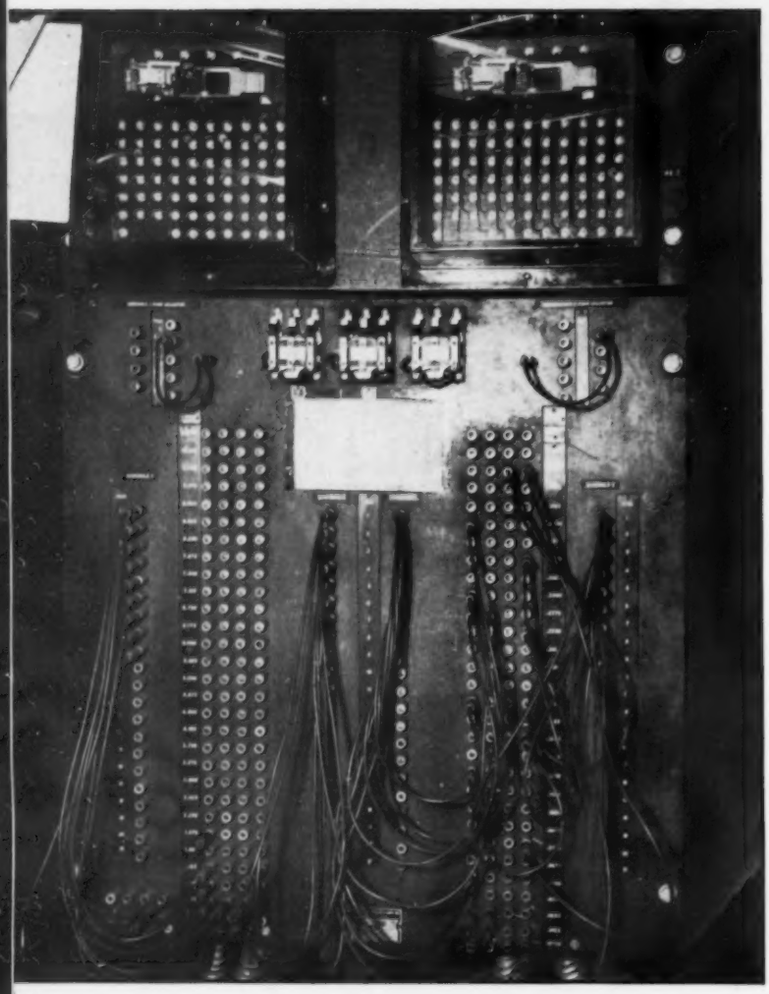
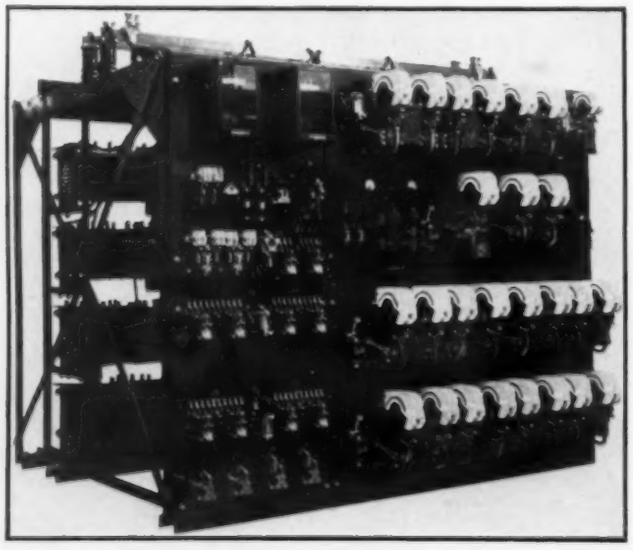


**Figure 3 — The plugboard has two schedules available and while one is in use the next can be set up.**

guards and edger on odd and even passes, and the automatic return to first pass conditions as preset.

At the top of the picture are two ratchet relays of the

**Figure 4 — The control panel for the plate mill screwdown is shown in this view.**



automatic telephone type, one for each schedule. By means of twenty-some contacts on each of six levels, they switch the automatic controls from pass to pass, and automatically return to pass-one conditions as preset. The effect of the long cord and plugs is to connect a fixed point on a ratchet relay to a fixed point on a potentiometer.

The panel on the left of Figure 4 contains relays and contactors concerned with the automatic control. The two at the top are polarized relays with front and back contacts for controlling the directional contactors of the screwdown and vernier motors. These relays are energized by the main and vernier potentiometers; are de-energized when the potentiometers are automatically balancd.

The panels on the right are the usual motor control. One interesting feature is the double-pole contactors which assure simultaneous control of the two 75 hp screwdown motors.

Figure 5 shows the control panels for the side-guard and edger motors. They are of the usual type and on automatic operation are also controlled by the preset pushbutton.

Figure 6 is an elementary diagram showing the control and operating mechanisms and the selsyn tie. Note that the selsyn tie functions as would a mechanical link-

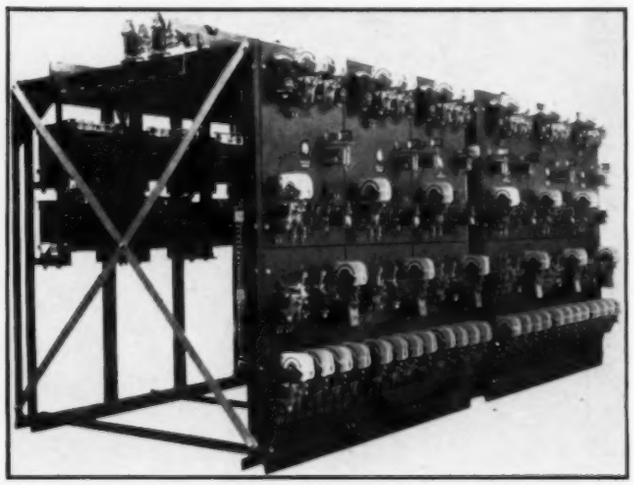


**Figure 5 — This is the control panel for the sideguards and vertical edgers of the plate mill.**

age of shafts and gears, only it is much simpler, and operates over wires at any distance.

Note first the two 75 hp motors, one for each screw, coupled together by a magnetic serrated-face clutch which is operable from the control pulpit to permit levelling the mill. The motor on the left drives a screw through worm and crown gear, and the worm shaft drives the selsyn transmitter. The selsyn receiver, through manually adjustable coupling, gears, and an automobile differential, drives a main rheostat and automatic cut-out. The segments of this main rheostat are permanently connected to the main potentiometer. When the main potentiometer is balanced, control of the screwdown motors, which as previously mentioned, has been started by the polarized relay on screw-

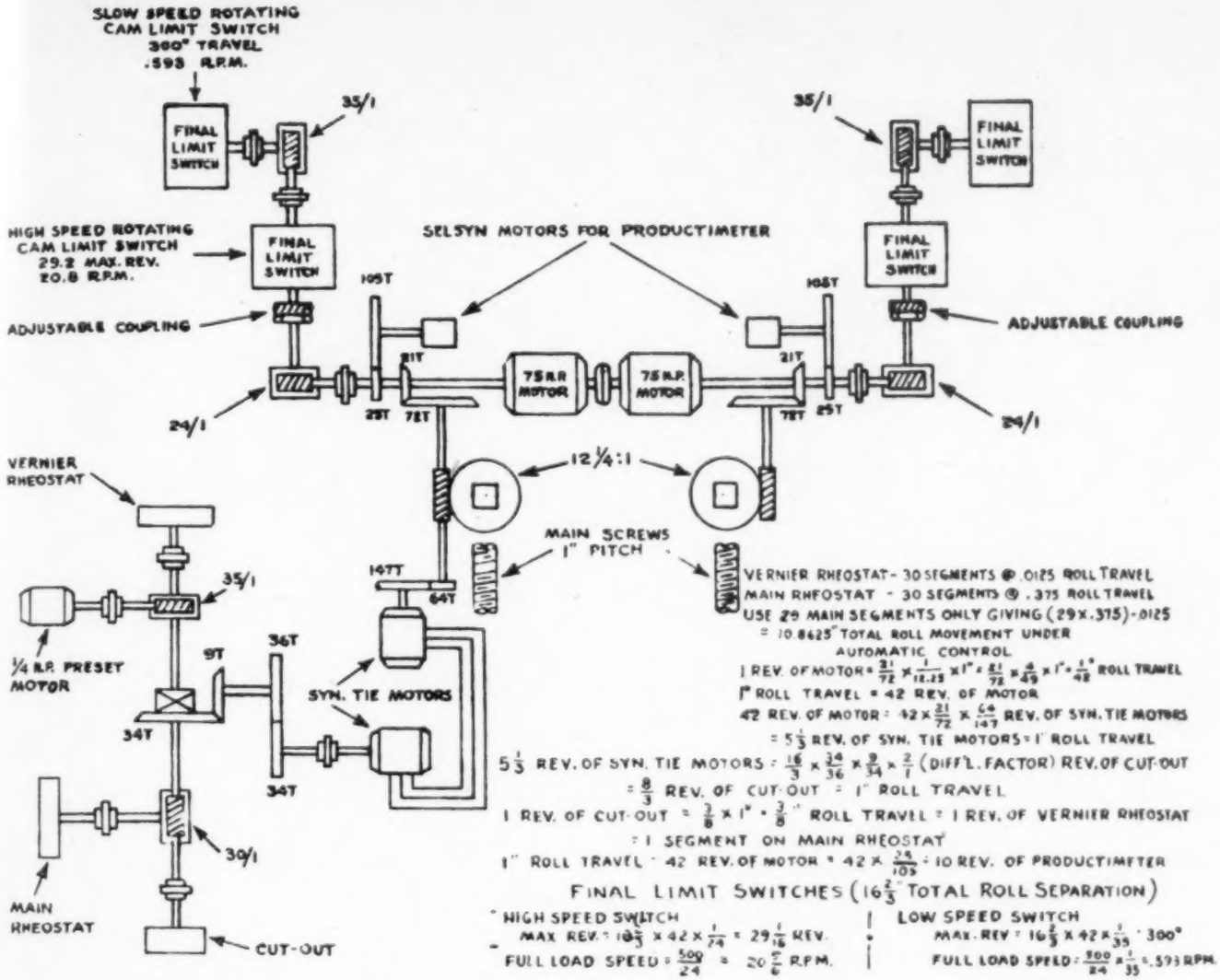

SLOW SPEED ROTATING CAM LIMIT SWITCH 300° TRAVEL .593 R.P.M.
FINAL LIMIT SWITCH
35/1
HIGH SPEED ROTATING CAM LIMIT SWITCH 29.2 MAX. REV. 20.8 R.P.M.
SELSYN MOTORS FOR PRODUCTIMETER
ADJUSTABLE COUPLING
10ST
21T
75 H.P. MOTOR
25T
72T
24/1
12¼:1
VERNIER RHEOSTAT
MAIN SCREWS 1" PITCH
14TT
64T
¼ H.P. PRESET MOTOR
9T
36T
SYN. TIE MOTORS
34T
30/1
MAIN RHEOSTAT
CUT-OUT
VERNIER RHEOSTAT - 30 SEGMENTS @ .0125 ROLL TRAVEL
MAIN RHEOSTAT - 30 SEGMENTS @ .375 ROLL TRAVEL
USE 29 MAIN SEGMENTS ONLY GIVING (29 X .375) - .0125 = 10.8625" TOTAL ROLL MOVEMENT UNDER AUTOMATIC CONTROL
1 REV. OF MOTOR = 31/72 X 1/18.25 X 1" = 31/72 X 4/49 X 1" = 1/42" ROLL TRAVEL
1" ROLL TRAVEL = 42 REV. OF MOTOR
42 REV. OF MOTOR = 42 X 21/72 X 64/147 REV. OF SYN. TIE MOTORS
= 5 1/3 REV. OF SYN. TIE MOTORS = 1" ROLL TRAVEL
5 1/3 REV. OF SYN. TIE MOTORS = 16/3 X 34/36 X 9/34 X 2/1 (DIFF'L. FACTOR) REV. OF CUT-OUT
= 8/3 REV. OF CUT-OUT = 1" ROLL TRAVEL
1 REV. OF CUT-OUT = 3/8 X 1" = 3/8" ROLL TRAVEL = 1 REV. OF VERNIER RHEOSTAT
= 1 SEGMENT ON MAIN RHEOSTAT
1" ROLL TRAVEL = 42 REV. OF MOTOR = 42 X 24/105 = 10 REV. OF PRODUCTIMETER
FINAL LIMIT SWITCHES (16 2/3" TOTAL ROLL SEPARATION)
HIGH SPEED SWITCH
MAX. REV. = 16 2/3 X 42 X 1/24 = 29 1/16 REV.
FULL LOAD SPEED = 500/24 = 20 5/6 R.P.M.
LOW SPEED SWITCH
MAX. REV = 16 2/3 X 42 X 1/35 = 300°
FULL LOAD SPEED = 500/24 X 1/35 = .593 R.P.M.

**Figure 6 — The elementary diagram shows the gearing and differential cut-out for the automatic, preset, screwdown controller.**

down panel, is transferred from this relay to the cut-out. The cut-out operates the usual slowdown and main contactors to stop the screws with the wiper of the main rheostat on the center of the balancing segment.

The vernier rheostat operates from a second potentiometer in a similar manner as the main rheostat, with the exception that it controls a ¼ hp motor used to rotate the cut-out switch and the main rheostat in advance of each pass, a predetermined amount called for by the vernier plug setup.

In order to insure accurate stopping of the screws, two stages of slowdown are incorporated in the control, both slowdowns consisting of armature shunt resistance. Obviously less maximum momentum will be experienced in the slowdown zones, while making small changes in the roll opening. However, under normal conditions of friction and of hydraulic lift on the upper roll, the final stop will be reached with the wiper of the main rheostat on the center of the balancing segment.

Limit switches are provided to impose upper and lower limits of travel of the screws. The pitch of the screws is so fine that they jam with great force in the case of over-travel.

Repeated manipulation of the cords eventually causes the stranded conductor to break. Such a break is signalled to the operator by the failure of the screwdown motors to start when he presses the automatic button.

After changing work rolls, it is necessary to coordinate the automatic control with the position of the rolls. This is accomplished by placing a thin block of known thickness between the rolls to gage the roll opening. Then the productimeters and dial are adjusted to that reading. With the electric tie between the selsyn transmitter and the receiver broken, the automatic control is operated to the same plugged-value, and the selsyn tie is closed.

Levelling the mill is accomplished by opening the magnetic clutch between the motors, and operating by manual control the screw which can operate independently of the selsyn transmitter.

As the polarized relays must be energized positively by 5 volts, it is essential to keep both the rheostat segments and wipers very clean. This is accomplished periodically by wiping with a cloth saturated with carbontetrachloride. A small resistance interposed by dirt on

wiper or segments, may cause the wiper to stop one segment short of the balancing segment.

## MECHANICAL FEATURES

By R. G. UHLER

Assistant Master Mechanic

Lukens Steel Company

Coatesville, Pennsylvania

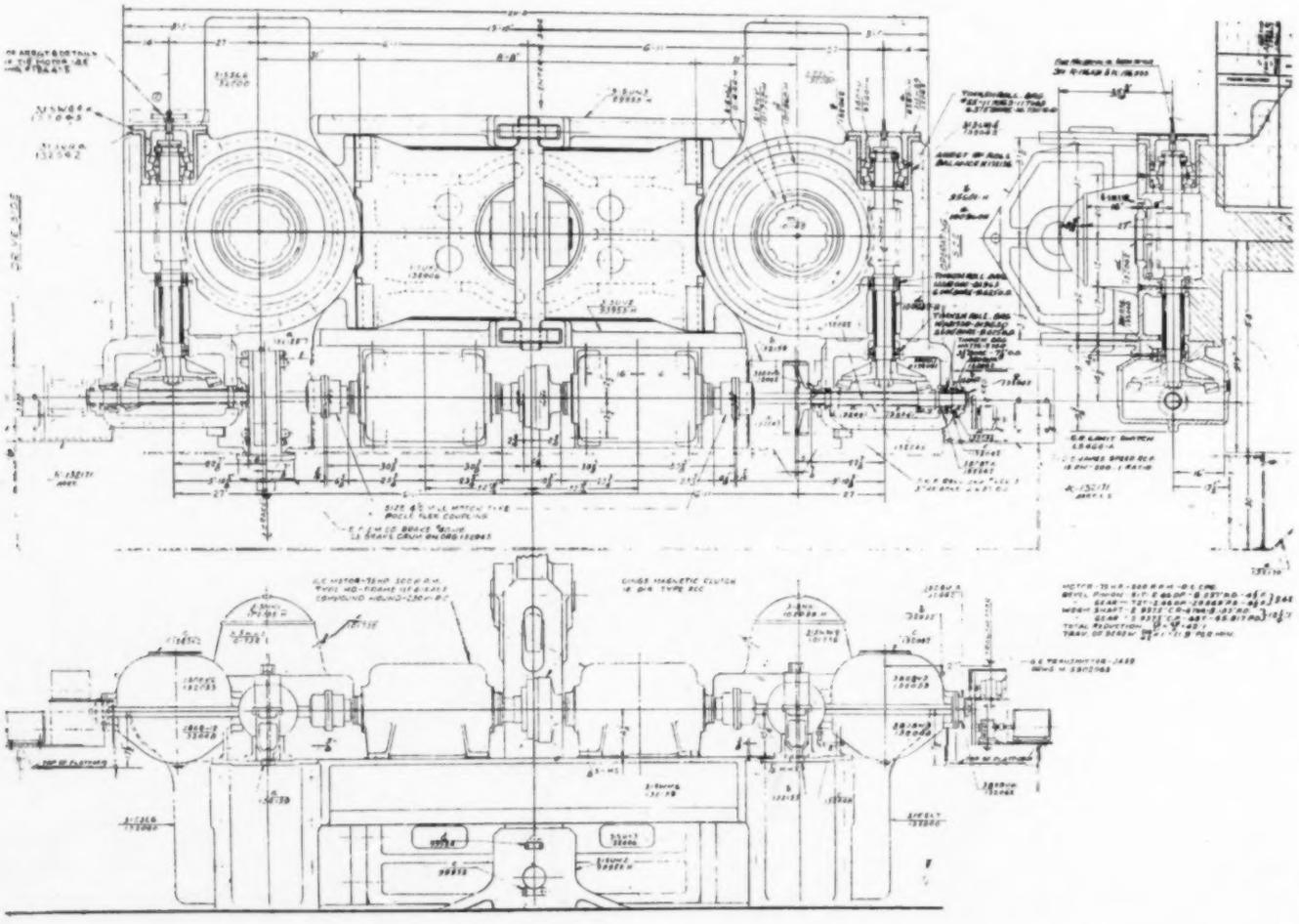
The mechanical department at Lukens has had some difficulties not experienced on other screwdowns, due to the reduction in power in the slowdown and final stages as described by Mr. Skalka. Figures 1 and 2 will give a general picture of the mechanical layout and enable study of the points of trouble.

Lubrication on the screwdown consisted of two parts: a circulating oil system which fed all shaft bearings and sprays all bevel gears, worms and worm wheels. An automatic grease system which lubricated the splines on the screw, the bushings, screws and screwboxes. This system also lubricates the work roll bearings, surfaces between chucks and housing, and the 24 in. attached edger.

When the mill was first started, a drag was noticed on the drive side in the final stages of the screw setting. A checkup showed lack of lubrication between screw and nut. As all other points had sufficient lubrication it was not desirable to increase the pump cycle. The largest valve available was installed at the stations for the screw and nut and this trouble was overcome.

Sometime later a drag again was noticeable. More lubrication helped little. The covers were removed from screwdown assembly and the various parts examined. The bushing in the top cover on the drive side of the mill was found to be cut and pulled. A check on lubrication showed that the inlet holes in the cast steel cover and the bronze bushing were not in line and had never been in alinement since the erection of the mill. The lubrication that this bushing had received came from other sources, grease that had worked down from the spline lead and oil that had worked in from the spray on the worm and worm wheel. The splines on the high carbon screw showed some wear and deformation from pressure. The splines on the cast steel worm wheel hub showed a minimum of wear. Proper oil lead holes were drilled, necessary grease grooves cut in the bushing and

**Figure 1 — The motor extension shaft has a 21 tooth bevel pinion mating with a 72 tooth bevel gear. The worm shaft is 4 thread with a 11¾ in. lead and the worm wheel is 49 tooth. The worm wheel center is made of cast steel.**



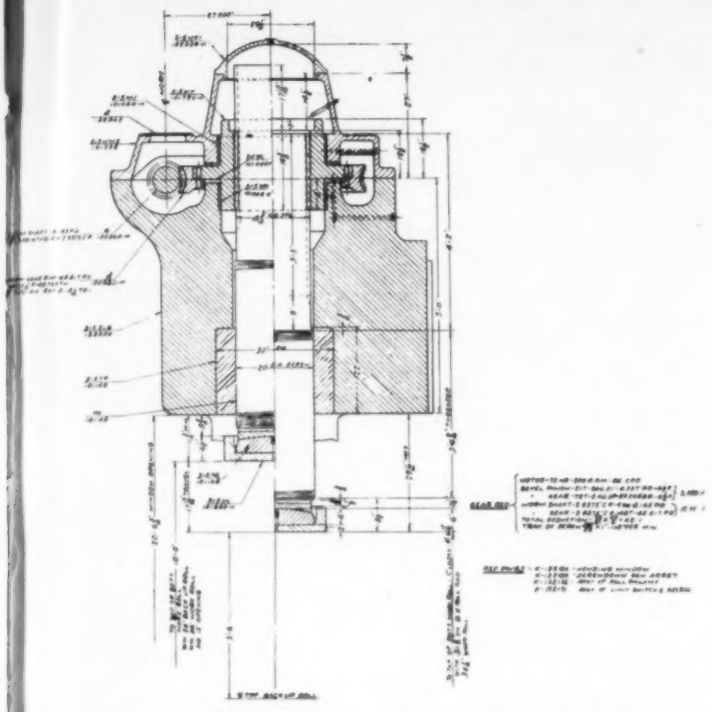


**Figure 2 — The screwbox is made of super strength grade B bronze. The screw is 0.60-0.70 per cent carbon forged steel, annealed, normalized, and drawn.**

all worn parts filed and honed. Examination of the same parts at later times have shown very little wear.

The travel on these screws is 13¾ in. The opening on the slotted guides on the 24 in. attached edger limits the maximum slab rolled to 7½ in. gage. The average is below this. Therefore, the work is done by these screws when they are extended 14 to 21 in. from the box. The mill is run to maximum opening only during mill change. Several months ago the drive side screw showed signs of dragging and showed a tendency to jam when run to the open position. The screw and box were removed from the mill and a new screw and box installed. When the box was examined, there was almost no wear or upsetting of the threads. The bottom threads of the screw showed a typical swelling effect. The working threads were upset on their upper edge to produce a thin sharp fin which could be more easily felt than seen. This amount of upsetting would produce little difficulty on our other mills with an ordinary screwdown. The threads on this screw were gaged to those on the corresponding screw box and they are now carried as spares.

One change has been made to the lubrication system. The valve stations for the screw and box were removed from the automatic system and piped to floor for grease gun connections. This was done for two reasons, first we have been able to lubricate the screws as often as necessary without over-greasing the remaining stations, and second it also has enabled the lubrication department to run test to find the best grease for that particular job.

The mechanical department's trouble with this screwdown has been more an annoyance than a delay factor. The greater sensitivity of this installation has increased considerably our understanding of screwdown operation. With the more enlightened approach thus gained we have been able to maintain our other, more conventional, screwdown equipment with greater intelligence.

The closer cooperation between the production, mechanical, and electrical departments made necessary in this instance, has naturally promoted more efficient maintenance and operation elsewhere in the mill.

# DISCUSSION

**PRESENTED BY**


**L. F. COFFIN, Superintendent, Mechanical Department, Bethlehem Steel Company, Sparrows Point, Baltimore 19, Maryland**

**H. H. ANGEL, Electrical Department, Bethlehem Steel Company, Sparrows Point, Baltimore 19, Maryland**

**JOSEPH F. SKALKA, General Foreman, 120 In. Mill Electrical Maintenance, Lukens Steel Company, Coatesville, Pennsylvania**

**R. W. COUCH, Assistant Superintendent of Maintenance, Saucon Division, Bethlehem Steel Company, Bethlehem, Pennsylvania**

**W. LOUIS BUNTING, Superintendent, Plate Mill, Lukens Steel Company, Coatesville, Pennsylvania**

**C. A. TUNNER, Assistant Superintendent, Bethlehem Steel Company, Bethlehem, Pennsylvania**


**L. F. Coffin:** One frequent difficulty in screwdowns is that the screws are not sufficiently highly polished. Unless the screw is highly polished, difficulty in dragging may be experienced in any screwdown control.

**H. H. Angel:** I noticed on the figures for the main drive that the limit switches, rheostats and other equipment are mounted at some remote point. I would like to know if any difficulty is encountered in starting up in cold weather, after a prolonged shut-down. In other words, is it necessary to have any heaters under the oil or grease which is in the selsyns or limit switches?

**Joseph F. Skalka:** The limit switches are mounted on the mill housing, and are geared directly to the screwdrive, through adjustable couplings. No trouble has been experienced due to starting cold.

**R. W. Couch:** I would like to know whether you attribute any increase in yield or any other definite savings to the installation of your automatic screwdown control. How does the accuracy of your roll setting compare with your mills that are manually operated?

**W. L. Bunting:** We had no figure to show improvements on yield due to automatic control but feel that it has its advantages of more even drafts. Therefore, it would give a more uniform gage plate which should improve the yield. The advantages of automatic control is that the percentages of drafts are predetermined and set up automatically before the operation starts. This can be worked out to the exact fraction of the percentages set up. With the old method of manual control an operator attempts to figure and arrive at his drafts between each pass. Manual control cannot always arrive at the exact per cent from pass to pass. He, therefore, uses more passes and tries to pick up on the next pass

that which he lost on the preceeding pass. He then has an uneven percentage of drafts from time to time.

**Joseph F. Skalka:** It is entirely feasible to take the manual control and disregard the preset control altogether, by just forgetting the automatic control entirely, and using the manual controller. If you want to go back to automatic control, you use the auto-button again.

Referring to the question on the selsyns, as to the oil being stiff, and whether they operate satisfactorily, we have experienced no trouble whatever with selsyns due to cold weather. Although in cold weather we usually have the switches in, before starting time, on the selsyns.

**Charles A. Tunner:** Would the author discuss the following:

1. What was the main factor that determined the installation of your preset screwdown control?
2. Do you improve the quality of your product by taking what is referred to as the proper draft on your initial passes?
3. The preset screwdown is installed on your 120 in. finishing mill. Therefore, if the product is improved by regulated drafting on the initial rolling operation after the ingot has been taken from the pits, would it not be advantageous from a quality standpoint to install the preset screwdown on the roughing or breakdown mill?
4. How do you compensate for expansion and contractions of rolls?
5. Assuming you have changed a set of rolls redressed to their minimum diameter, how is setup man notified, and if not notified how would he make the necessary corrections from his previous setup?
6. Who is responsible for the preset schedule to be followed by the roller?
7. In your opinion does the installation of a preset screwdown materially reduce or effect the preparation costs of the shipped product?
8. What percentage increase in tonnage would you attribute to the installation of the preset screwdown?

**Joseph F. Skalka:** The following are the replies to the questions by Mr. Tunner, each paragraph number refers to the corresponding numbered question:

1. Time saving between passes, and fewer passes, less mental fatigue in pulpit operator, fewer spoiled plates.
2. Greater uniformity of unannealed plates.
3. Ingots and slabs are in the roughing mill so short a time, and passes are so short, that any time saved would be negligible.
4. By adjustable couplings on limit switches, productimeters, and dial, same as with manual controls.
5. Newly ground rolls come to the mill with diameters painted on them. Corresponding adjustments are made on limit switches, productimeters, and dial. All adjustments can be checked by placing a copper pad of known thickness between the rolls, but resort to this is rarely found necessary.
6. Mill superintendent.
7. Yes. See answer to one above.
8. This question was discussed previously by W. L. Bunting.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# The Powder Process in Stainless Steel Production

By C. J. BURCH and
E. M. HOLUB
The Linde Air Products Company

***. . . . the use of metallic powders provides a versatile and economical process for cutting and scarfing a large variety of alloy compositions at any stage from the ingot to the finished product . . . .***

▲STAINLESS steels were developed to meet the demand for materials that would withstand corrosion. How well this group of ferrous alloys has met this demand is shown by their ever-increasing sales. Their production, however, brought a great many problems to the steel industry. Not the least of these was how to cut, condition and fashion these materials. Steel men, with a world demand for tougher and more corrosion-resistant materials, were faced with the problem of producing even stronger materials for tools to work them. Millers, planers, grinders, and saws were the only available machines for cutting and conditioning stainless steels. The cost of these tools was high and their production rates were far below those obtained when used on carbon steels. Examination of the slow and difficult methods of working stainless steels, as practiced in the period preceding World War II, reveals a similarity to the period that the carbon and low-alloy steels had to pass through following World War I; for until the full development of the oxy-acetylene processes, these plain carbon steels were also cut and worked largely by mechanical means.

During the period of growth and expansion in which the alloy producers were striving desperately to increase production, many unique and helpful means of cutting oxidation-resistant materials were discovered. To mention but a few, there was the oscillatory oxy-acetylene cutting method, the electric arc method, and the rod feed method. In the oscillatory method, an oscillating motion is imparted to an oxy-acetylene blowpipe equipped with an oversized nozzle, and by a combination oxidation, melting, and blowing action, a slow severing cut can be made. The electric arc combination, with either a metallic or a carbon electrode, provides another slow method for severing, which consists of a purely melting action. The rod feed method consists of feeding an iron rod into the reaction zone of an oxy-acetylene nozzle, where the rod melts and burns to form iron oxide, which acts as a fluxing agent in clearing the kerf of oxidation-resistant materials. These methods accomplished the job for which they were designed, but they were slow and tedious. None of these methods were effective for scarfing.

The very characteristics of corrosion and oxidation resistance that stainless steel possesses made impractical the use of conventional oxy-acetylene processes which had first proved a boon to carbon steel production a decade or so ago. The elements which impart the desirable qualities to stainless steels are chromium and nickel.

Nickel cannot be oxidized readily and is therefore removed in the molten state as part of the slag. In the amounts employed in stainless steel, however, it does not seriously effect the cutting or scarfing reaction. Chromium, on the other hand, while it oxidizes readily at elevated temperature, develops a highly refractory oxide. In cutting, this refractory formation covers the walls of the surface and prevents any further oxidation until it has been removed.

In the powder process there is fed into the reaction zone a powdered material which gives increased heat and which serves as a fluxing agent to remove the refractory chromium oxide and the non-oxidized nickel. A great number of materials have been tested. The most effective, economical, and non-injurious from a health standpoint is iron-rich powder of fine mesh size.

## APPARATUS

In the powder process, the one piece of equipment that is common to all operations is the powder dispenser, shown in Figure 1. It consists of a storage hopper, fitted at its base with an ejector unit which dispenses the powder into a hose, through which it is conveyed by air. For normal cutting operations the hopper contains enough powder for eight hours operation. The dispenser requires an air supply of only from 2 to 20 psi depending upon the flow rate of powder required.

In scarfing operations, the powder is mixed with the cutting oxygen within the scarfing nozzle and issues from the oxygen orifice as a finely-dispersed powder cloud. In cutting operations, powder is introduced into the cutting reaction zone from outside the preheat flames. This procedure allows full utilization of the cor-

Presented before AISE Annual Convention, Pittsburgh, Pennsylvania, September 22, 1947

Figure 1 — The powder dispenser is required in all the operations of the powder process.

rect cutting-oxygen pressure and allows the powder to be effectively heated to its ignition temperature.

For hand-scarfing, a 44 in. long blowpipe is provided, shown in Figure 2. This powder-scarfing blowpipe, as it is called, has all the features of a standard oxy-acetylene blowpipe, plus a third tube connecting the rear body to the blowpipe head. This tube carries powder from the powder valve, which is an integral part of the rear body, to the blowpipe head, where the powder is introduced into the nozzle. The powder valve is actuated by the same lever that operates the cutting-oxygen valve. The valves are so arranged that the powder valve opens slightly ahead of the cutting oxygen valve to assure instantaneous starts on cutting and scarfing. Thus, no time is lost preheating, nor is it necessary to start on a sharp edge.

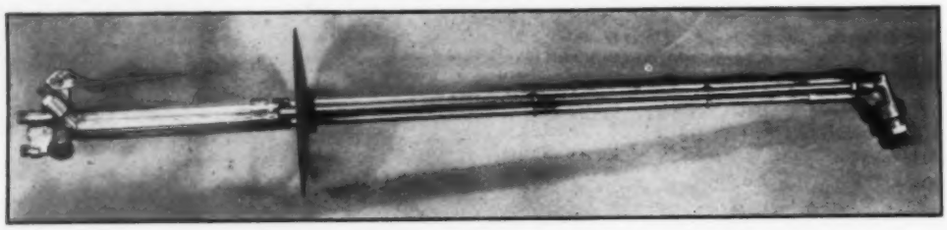


Figure 2 — The hand scarfing blowpipe here shown is 44 in. long.

For machine-cutting, standard oxy-acetylene or oxy-fuel gas blowpipes and nozzles are used in combination with an attachment for introducing the powder into the reaction zone and an arrangement for conveying the powder to the powder attachment. The attachment, shown in Figure 3, is an external nozzle that envelops a standard cutting nozzle; it is so designed that the same nozzle nut holds both the attachment and the cutting nozzle concentrically alined in the blowpipe. This attachment is made in four sizes to fit all blowpipes, so that materials from $\frac{1}{8}$ to 31 in. thick can be cut successfully.

For hand-cutting, a 28-in. long powder blowpipe is provided. This hand blowpipe is similar to the scarfing blowpipe in all respects, except in length. The nozzles employed are of two-piece construction. They consist of the nozzle body, which contains the cutting oxygen and preheat orifices, and an outer sleeve which directs the powder flow through the preheat flames into the cutting oxygen stream. An attachment similar in principle to the one provided for machine cutting has been developed for use with standard hand-cutting blowpipes.

In both the machine-cutting and hand-cutting attachments and the hand-cutting nozzles, the powder is introduced into the cutting-oxygen stream at such an angle that the powder and oxygen meet approximately 1 in. below the nozzle face. This distance is provided to allow the powder sufficient time to begin burning and thus provide its own exothermic reaction. The scarfing nozzle, on the other hand, is carried $2\frac{1}{2}$ to 3 in. above the work and used at an angle of 30 degrees with the horizontal. This greater distance is provided because the powder particles mixed with the oxygen are moving at considerably higher speed than in the cutting nozzles and thus require a greater distance in which to arrive at their ignition temperature.

## OPERATING CHARACTERISTICS AND RESULTS

The cutting speeds attained on stainless steels are comparable to those obtained on equivalent thicknesses of carbon steels. The cutting-oxygen pressures, how-

Figure 3 — The machine cutting powder attachment is a nozzle which envelopes a standard cutting nozzle.

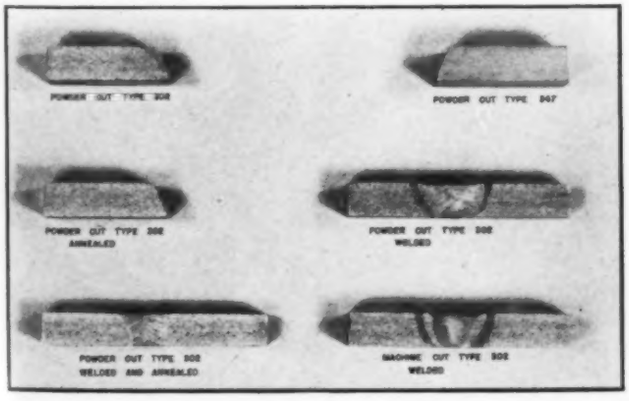
**Figure 4 — The technique of slab scarfing consists of directing the slag being formed onto the surface already scarfed.**

ever, are increased slightly, and one size larger nozzle is employed. Powder flow varies from 15 to 45 lb. per hr, depending upon the thickness of the material being cut, the greater thicknesses requiring the larger powder flows.

In hand-scarfing, the oxygen pressures are comparable to those used on carbon steels, but the speeds attained are from 60 to 70 per cent lower, varying with depth of defect to be removed and with the alloy content of the material. The powder flow requirements are from 30 to 75 lb per hr, depending upon the quality of scarfed surface desired, a very smooth surface requiring the larger powder flow.

There are two fundamental differences between the oxy-acetylene scarfing of carbon steels and powder-scarfing of stainless steels: the smoke resulting from powder-scarfing is much more voluminous and dense; and the slag produced is much more tenacious. The smoke produced by the powder process is non-toxic, but for operator convenience, it should be removed for

**Figure 5 — These metallurgical samples show the effect of cutting and welding stainless steels.**




efficient working conditions. Simple suction fans are used for accomplishing this task in several mills. It is best to mount the fans in the walls of the building, and scarfing should be carried out with the stream directed toward the inlet of the fans. In this manner, smoke removal can be made so complete that powder-scarfing can work side by side with other operations.

Since the slag produced during powder-scarfing operations is entirely different from that resulting from working on carbon steel, a slightly different scarfing technique is required. The procedure consists of directing the slag being formed onto the already scarfed surface as shown in Figure 4. This results in several repeated coolings and heatings of the already solidified slag. This method of operation is entirely contrary to the procedure followed in the scarfing of carbon steels, but does result in an easy removal of powder-scarfing slag. In the beginning it was considered necessary to remove slag before rolling, in order to insure a quality product. Recent findings have indicated that this slag removal

**Figure 6 — Powder cutting has been found very useful in handling stainless steel scrap such as the spill here shown.**

is not necessary, since it will break free from the work in reheating furnaces preparatory to rolling. A chemical analysis of the slag reveals that it is approximately 20 per cent chromium and nickel oxides, with the remainder iron oxide, depending of course upon the analysis of the material scarfed. It has been found valuable as a charging product for electric furnaces, and its value is estimated at $60.00 per ton. This credit adds further to the economical advantage of the powder process as contrasted to grinding, where the residue is normally worthless.

With the introduction of the powder-scarfing process, the question was frequently raised as to the possible surface contamination of a scarfed material. Furthermore, fear was expressed of a possible carbon and iron pickup, due to the iron-rich powder used. The re-

sults of intensive investigations has proved satisfactorily that a scarfed area is in no way affected chemically.

There are metallurgical effects resulting from powder-cutting that are always associated with localized heating of certain types of stainless steel. These effects are not present in the stabilized types, such as 321 and 347. Types 302, 304, and others have an area adjacent to the cut face that has carbide precipitation. The depth of this effect is rarely, if ever, greater than ¼ in. The amount of carbide precipitation does not seriously affect corrosion resistance of stainless steels, but it is well to know that such a condition exists. As is well known, in welding of stainless steels these areas of carbide precipitation can be removed by subsequent annealing or heat treatment.

No further preparation other than a light grind, is required on plates to be welded. As shown in Figure 5, plates that have been powder-cut and welded exhibit identical appearances with those that were machined and welded as far as corrosion resistance is concerned. Also shown is the fact that stabilized Type 347 does not exhibit any affected zone and that the zone is removed on Type 302 when the material is subsequently annealed.

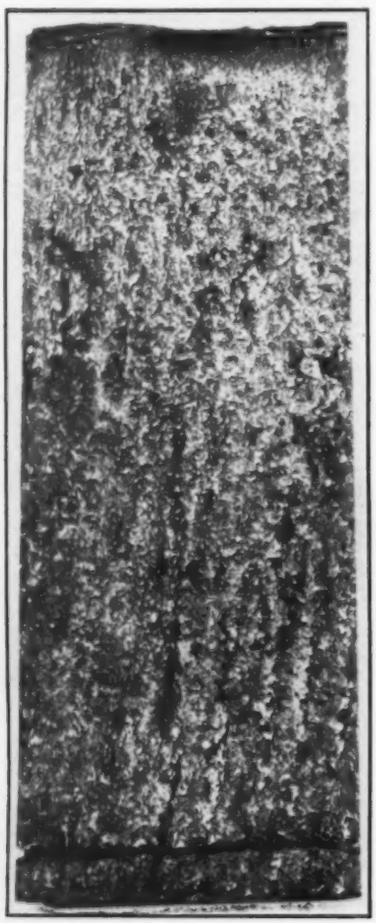


**Figure 7 — A hot top section of an 18-8 ingot 14 in. thick is here shown.**

## PROCESS APPLICATIONS

To appreciate fully the position that the powder-scarfing and powder-cutting process now commands in the steel industry, one should follow alloy steels from their beginning in the electric furnace, through the various steps of processing, until they emerge as finished materials in the form of sheets, bars, or shapes. In fact, powder-cutting is used before the materials reach the electric furnace—in the preparation of stainless steel scrap as shown in Figure 6.

**Figure 8 — The ingot in this photograph has a characteristic spongy surface.**

Various defects in ingots require removal before further processing. In some cases, hot-top sections or badly cracked portions of the ingot may need to be removed in order to facilitate handling or to assure a better-rolled product. The maximum thickness that the powder process has cut to date is 30 inches. Complete severing cuts can be made on this thickness of material at a cutting speed of approximately 2 in. per min. Thus, a 28-in. by 55-in. section may be severed in 22 minutes at a cost of $10.00 which is less than ½ cent per sq in. of cross-sectional area. Figure 7 illustrates a hot top section 14 in. thick.

Badly cracked ingots or ingots to which masses of

**Figure 9 — The appearance of the ingot after scarfing is shown in this photograph.**

mold iron adhere, may be conditioned very economically before further processing. Spot conditioning by powder-scarfing will help to eliminate the tendency of the surface to break up during rolling in the blooming mill. Mold iron is removed by the combined use of cutting and scarfing, and the technique employed is largely dependent upon the shape and size of the adhering iron. Mold iron is removed at a rate of 75 lb per hr, at a total cost of about 10 to 12 cents per pound of metal removed. Conditioning of the ingot is accomplished at a rate of 100 lb per hr, at a cost of 10 cents per pound of metal removed.

Figure 8 illustrates an ingot, showing clearly the surface of an alloy in this form. The material, although it does not show checks or cracks, is covered by a typical spongy surface. Experience has shown that conditioning metal in this form produces a better-rolled product than an identical ingot rolled in the unconditioned state. In the past, consideration could not have been given to the conditioning of all ingots because of the high cost of grinding. Now, however, with the powder-scarfing process, which enables ingots to be conditioned in one-sixth to one-fourth the time required by grinding, ingot conditioning can be carried out economically. Figure 9 illustrates the appearance of a typical powder-scarfed ingot. It might appear that the rough surface illustrated would not produce a quality surface in the finished product, but innumerable tests have definitely proved that the surface produced on the ingot will roll out to a blemish-free product. Heats of 22 to 26 ingots, with a total weight of approximately 13 tons, have been powder-scarfed in 20 man-hours.

**Figure 10—Defects during the rolling of the ingot sometimes occur and such an instance is shown in this bloomdown. Conditioning can save most of this material.**

During rolling of an ingot, cracks and defects may occur at some intermediate stage which make it inadvisable to continue the reduction to the desired finished slab or bloom. Such a condition is shown in Figure 10. This intermediate section of bloomdown is allowed to cool and is then conditioned prior to further rolling.

Powder-cutting is used to remove badly cracked corner sections, as shown in Figure 11. As an example, the

**Figure 11 — The corner of this scarfed bloomdown has been powder cut.**

average cost to remove one corner on a 16-in. by 37½-in. by 100-in. bloomdown was $4.75. Bevel cuts on the corners of 17-in. by 32-in. by 118-in. bloomdowns, in which 600 lb of metal were removed, showed a cost of 7 cents per pound of metal removed. The reason that conditioning is carried out in this manner is two-fold: bevel-cutting is more rapid than scarfing to a great depth; and the scrap which results from this cutting operation is more valuable than the rechargeable slag formed by the scarfing process.

In the cases where corner cracks do not extend to any appreciable depth, but cracks occur over the entire surface, scarfing is used. A typical set-up for this operation is shown in Figure 12 where the scarfing blowpipe is mounted on a motor-driven carriage that operates on a gantry-mounted track. The original bloomdown surface and the scarfed surface are contrasted in Figure 13.

A 12-in. by 37½-in. by 99-in. bloomdown was conditioned by scarfing in 7.5 hours; 1,000 lb of metal were removed at a total cost of $90.00, or 9 cents per pound

**Figure 12 — A typical setup for scarfing bloomdown cracks which occur over the entire surface is shown.**

**Figure 13 — This photograph gives a close-up of a partially scarfed bloomdown. Note the contrast between the original and the scarfed surface.**

of metal removed. In general it can be stated that the time for powder-scarfing bloomdowns is one-quarter that required for grinding, and the cost is one-half or less. Deep defects that remain after overall scarfing are removed by secondary spot-scarfing with hand blowpipes.

The scarfing process is particularly useful on material that is badly broken up, because a scarfing pass can remove metal to a depth of from $\frac{1}{16}$ to $\frac{1}{2}$ in. with less variance in time factor than a grinding wheel. On material that would have to be considered scrap if grinding was the only conditioning medium available, powder-scarfing shows very great saving.

Stainless steel slabs are normally sheared to length immediately following rolling on the slab mill. However, conditions do arise which make it impractical to shear to length for custom work, and in those instances powder-cutting makes it possible to overcome obstacles that would hinder normal production schedules. Cobbles, cut-backs, and dog-earing are also fields of application for powder-cutting. The portability of the cutting equipment facilitates these applications.

Cobbles resulting from mechanical failure of mill equipment may be salvaged by powder-cutting the slab to the specified lengths, and at the same time cutting the crop ends to charging-box size. Defective ends may be removed from the sheared slab where such cut-backs are warranted or where additional test pieces are required. Slabs for plate use can be cut to any specified length or width to suit special orders or plate mill handling capacity.

Dog-earing, which is corner-cutting of slabs for rolling into wide plates, produces square ends in the rolled product, increasing the capacity and accuracy of the plate mill.

Figure 14 illustrates the cutting of slabs to size by the powder process. Actual cost analyses on this type of work show that, on the average, sawing removes 50 to 80 per cent more metal per cut in kerf width than does powder-cutting and is $2\frac{1}{2}$ times more costly on identical material. As an example, in sizing a slab 5 in. thick by 40 in. wide, the kerf width by sawing was $\frac{1}{2}$ in. as compared to only $\frac{5}{16}$ in. by powder-cutting. In making five cuts on a slab 40 in. wide, this represents a saving of 50 lb of metal. In addition, powder-cutting will produce four to six times greater volume of work in a given period of time.

In producing slabs from unconditioned ingots, the slabs will often show badly cracked edges. These cracks, in extreme cases, may extend several inches into the material and must be completely removed before rerolling of the slab. It is usual practice today, after conditioning the surfaces of such slabs, to make trimming cuts on the edges.

One of the most critical points at which conditioning is applied is while material is in the slab form. At this point, which is usually prior to the final hot-rolling, the quality of the surface is responsible, in large measure, for the quality of the finished sheet. In general, surface defects are rather shallow as shown in Figure 15, if proper practices and conditioning have been followed in earlier stages. Usually a relatively light cut or scarf is all that is necessary. Where only a very light finish cut is required, powder scarfing has not yet proved practicable. Where the metal removal necessary to remove all defects is 2 per cent or greater, scarfing should be considered. Scarfing may also be used for spot conditioning of deeper defects where an overall light grind is used. On some types of slabs, such as Type 310, defects will be very numerous and tend to run deeper than other grades. Scarfing of this slab material is indicated and has proven economical and satisfactory. The scarfing operation is carried out in one-half to one-third the time required for grinding down the equivalent amount of metal.

A good surfaced slab, requiring overall conditioning with a metal removal of $2\frac{1}{2}$ per cent, may be hand scarfed at a rate of 0.7 ton per man-hour. For 5 per cent metal removal, hand scarfing will produce 0.6 ton per man-hour, or single-blowpipe machine scarfing will produce 0.9 ton per man-hour. Normal grinding production on slabs of the same section and weight is in the neighborhood of 0.4 ton per man-hour for the low metal loss, and 0.25 ton per man-hour for higher metal loss. The

**Figure 14 — These slabs are being cut to size for rerolling on a plate mill.**

**Figure 15 — In the slab form, surface defects are rather shallow.**

basic cost for removing stainless steel by scarfing, including all items, varies between 12 cents and 23 cents per lb of metal removed. On comparable work, grinding costs will run between 19 cents and 28 cents per pound of metal removed.

It has been reported in several instances that scarfed material produces a better-rolled product than does ground material. This is attributed to the fact that in scarfing it is impossible to close up defects, but rather the process clearly shows up any imperfections in the reaction zone. This is not the case in grinding, where it is possible to "smear" closed shallow defects, which will show up in an exaggerated condition after rolling. This is particularly true on the higher alloy grades, such as Type 310. Figure 16 shows billets, one of which has received a spot-conditioning operation by the powder-scarfing process, while the other has been completely scarfed on one surface. This type of operation is accomplished by scarfing in one-sixth to one-eighth the time required for grinding. On the type of material illustrated, 54 billets were spot-scarfed in 7 hours, while 6 billets were ground in 8 hours.

Figures 17 and 18 illustrate a 7-in. by 8-in. by 80-in. billet before and after scarfing. All billets in this heat were badly cracked, and after a short grinding period on several billets consideration was given to scrapping the heat. However, by the use of the powder process, these billets were reclaimed to produce first quality material, and the scarfing time was only one-half hour per billet.

Although most steel mill cutting is on heavy sections, the powder process is not limited to thick material; it does an excellent job on plate. Plate cutting is being successfully carried out on material ranging in thickness from $\frac{1}{8}$ in. up. Figure 19 illustrates typical powder-cut edges on various thicknesses of stainless steel. This work is being done in steel mills for the preparation of plate for sandwiches for clad material, and also for the purpose of sizing material to customers' specifications. Table 1 gives cutting data for 18-8 stainless steel, containing operating data and consumption figures.

**TABLE I**
**Powder Cutting Data**
**Clean 18-8 Stainless Steel**

| Thickness, in. | Nozzle size | Cutting oxygen, psi | Powder consumption, lb per hr | Cutting speed, in. per min |
|---|---|---|---|---|
| ¼ | 4 | 50 | 15 | 24 |
| ½ | 6 | 50 | 18 | 20 |
| 1 | 6 | 50 | 18 | 15 |
| 2 | 8 | 50 | 18 | 11 |
| 4 | 10 | 50 | 18 | 7 |
| 6 | 12 | 50 | 22 | 5 |
| 8 | 14 | 65 | 24 | 4 |
| 10 | 16 | 65 | 24 | 4 |
| 12 | 20 | 75 | 30 | 4 |
| 14 | 20 | 75 | 45 | 3 |
| 16 | 24 | 75 | 45 | 3 |
| 18 | 24 | 75 | 45 | 2 |
| 20 | 24 | 75 | 45 | 2 |

In addition to the successful application that pow-

**Figure 16 — On the top is shown a spot scarfed billet. A completely scarfed billet is shown in the bottom of the photograph.**

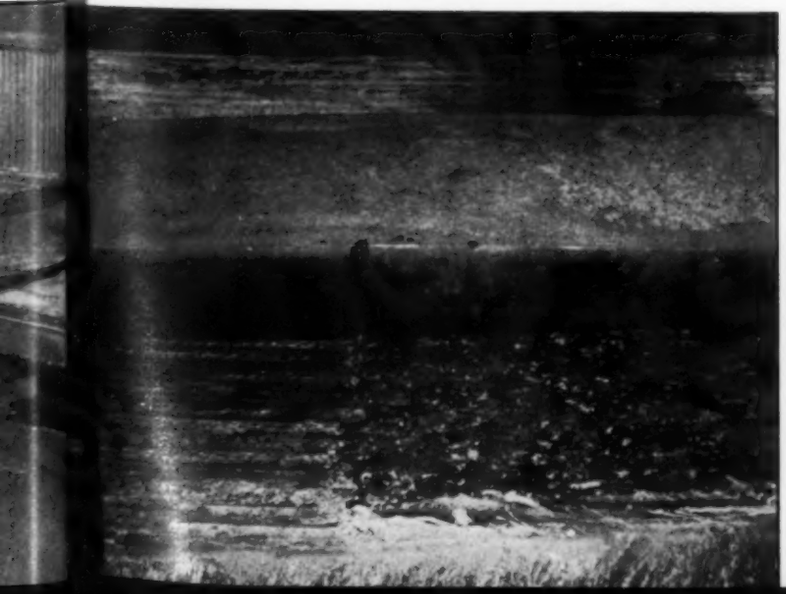


**Figure 17 — In this unscarfed billet are shown some very deep corner breaks.**

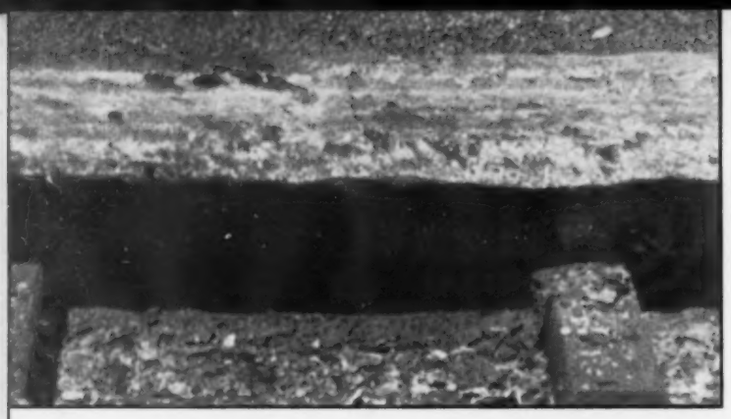


**Figure 18 — The appearance of the billet given in Figure 17 is shown after scarfing in this illustration.**

der-cutting has on stainless and other high alloy materials, there remains one very important cutting operation which is finding increasing use in the steel mills. This is the cutting of cast iron, which is carried out with the same ease and accuracy of operation as work on stainless steels. In scrapping operations, cast iron rolls up to 31 in. in diameter have been successfully cut at speeds of 1½ in. per min. Smaller diameter sections are cut in a proportionately faster time.

Another cast iron cutting operation which has gained considerable favor is the trimming of lumps from ingot molds. In the making of a mold, the sand casting may fail at some point, with the result that the molten metal being poured fills this cavity and, upon solidfication,

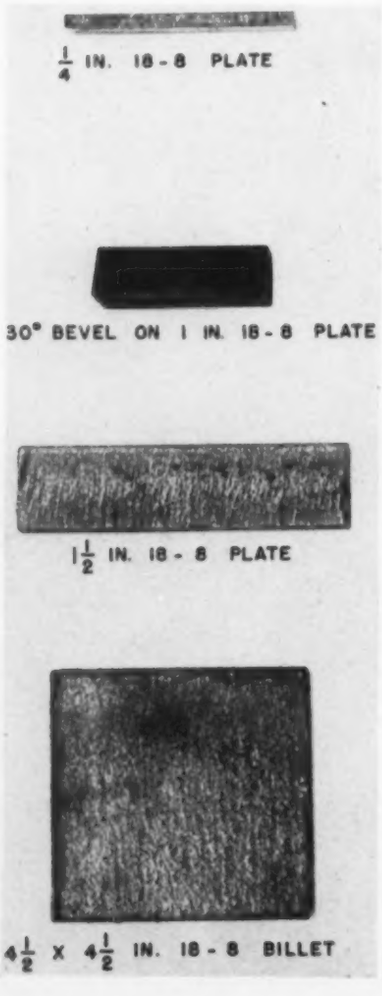



**Figure 19 — The characteristic appearance of powdercut surfaces on various thicknesses of stainless is shown in these four sketches.**

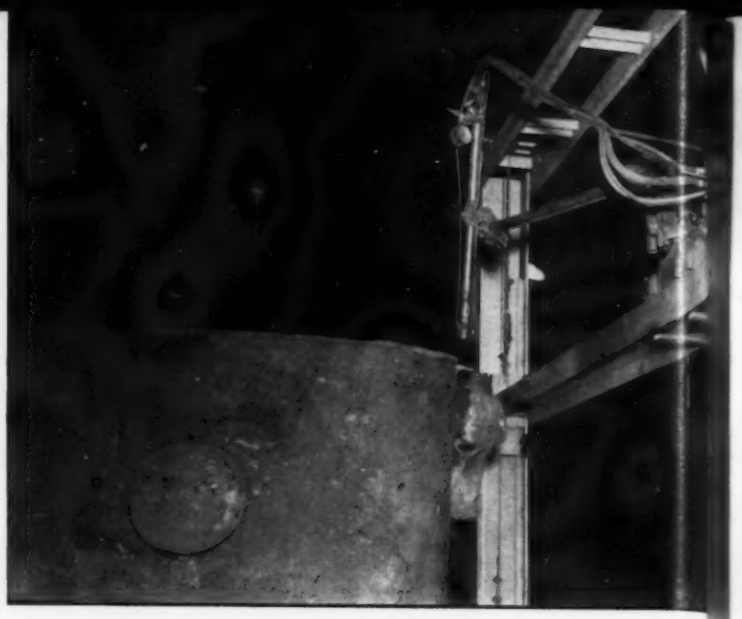
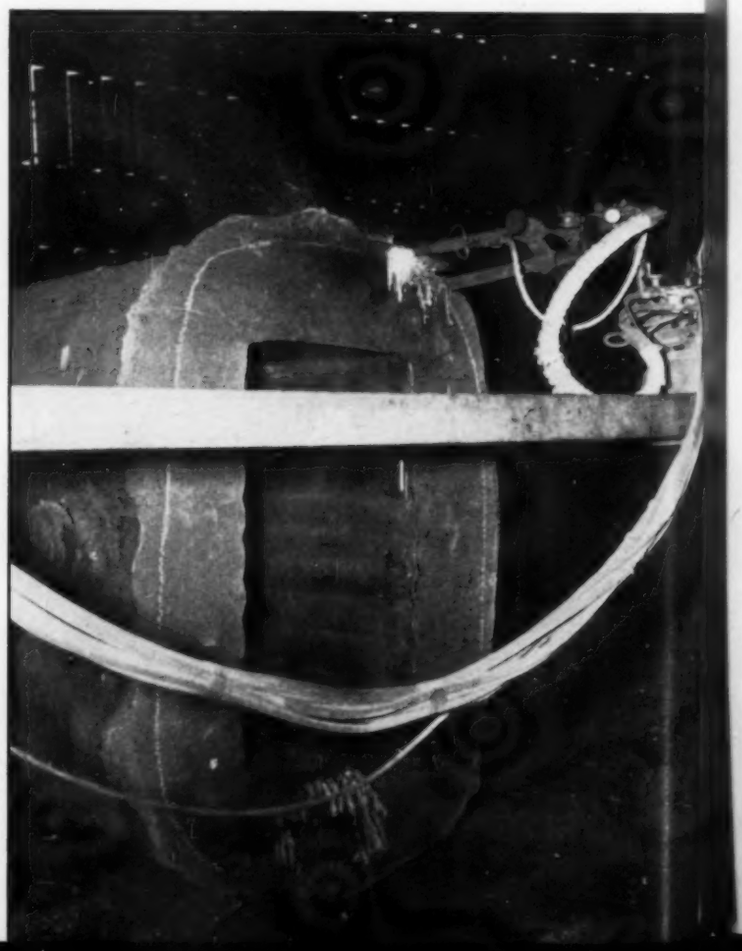


**Figure 20 — This view shows a production setup for the removal of lumps from ingot molds.**

the mold has a lump along its exterior. Formerly this mold had to be scrapped, since grinding was tedious and an uneconomical solution to the removal of this flaw. Today, however, thousands of dollars are being saved in the steel mill foundries merely by powder-cutting these lumps from the mold. A setup for carrying out this operation is shown in Figure 20. Lumps as great as 24 in. thick have been successfully and economically trimmed from molds. The powder-process is also used

**Figure 21 — Another cast iron cutting operation in which powder cutting is found of use is in the trimming of flash from ingot molds.**



for trimming flash from molds as shown in Figure 21.

Many times jobs arise which are not part of a production setup but which are essential to the economic welfare of a mill. An illustration of this type of problem is one which arose recently where a considerable volume of stainless angles were rolled with the wrong size flanges. It was a simple matter to powder-cut the angles to size, and thus increase their value from $93.00 a ton as scrap to $2,000.00 a ton as salable products. The angles were 20 ft. long, and a tolerance of 1/16 in. was held along the entire length. Without powder-cutting, this customer admittedly would have lost thousands of dollars.

Since the commercial introduction of the powder process almost three years ago, its use has expanded until the active users are numbered in the hundreds. The use of a metallic powder provides a versatile process capable of handling a wide variety of alloy compositions with equal facility from ingot form to finished product, and has brought increased economies to the production of stainless steels.

# DISCUSSION

PRESENTED BY

ROY P. TOOKE, General Superintendent, American Rolling Mill Company, Butler, Pennsylvania

C. J. BURCH, Service Supervisor, Pittsburgh District, Linde Air Products Company, Pittsburgh, Pennsylvania

FRANK A. SNYDER, Assistant Divisional Superintendent of Rolling Mills, Carnegie-Illinois Steel Corporation, Chicago, Illinois

E. M. HOLUB, Development Engineer, Linde Air Products Company, Newark, New Jersey

E. D. GIBSON, Superintendent, Steel Conditioning, Republic Steel Corporation, Canton, Ohio

F. C. HULL, Metallurgical Research Engineer, Research Department, Westinghouse Electric Corporation, East Pittsburgh, Pennsylvania

RALPH FAIR, Research Chemist, Simonds Abrasive Company, Philadelphia, Pennsylvania

THOMAS S. McNEELY, General Grinding Foreman, Crucible Steel Company of America, Midland, Pennsylvania

JOHN H. VOHR, Assistant General Superintendent, Carnegie-Illinois Steel Corporation, Chicago, Illinois

**Roy P. Tooke:** Your statement on the value of the slag in the electric furnace, is that an estimate, or is it a wishful thought, or does it have a good deal of background?

**C. J. Burch:** That, of course, depends entirely on the individual case. The value stated happens to be one of the rates that we were given as a value of the material. The slag contains about 20 per cent of chromium oxide and nickel oxide, with the remainder iron oxide. If you did not count on recovering that material, you would not value it very highly, but if you take credit for the metallic content, it works out to be about sixty dollars a ton. Other places may not value it as highly, and possibly you do not.

**Frank A. Snyder:** There is one particular point where it was said that the conditioning of ingots was probably economical. That is a little bit questionable. I think probably that the intermediate conditioning of ingots may be economical where there is need for very close tolerances on the finished product, but to condition the ingots themselves is questionable, because about 80 or 90 per cent of them go down to the finished product. The same grinding is required on the finished slab, if you conditioned the ingots.

**E. M. Holub:** The statement regarding ingot conditioning was made in view of recent tests which have borne out the fact that ingots either completely skinned or spot-scarfed resulted in a better yield. It is just an indication but it appears fairly reliable.

**Frank A. Snyder:** I think there is another application you did not mention, and that is the burning of head-shear scrap in bundles. Are you familiar with that application?

**E. M. Holub:** Yes, 1/4-in. thick scrap from head shearing circles is stacked in approximately 2-ft. high bundles. Originally this material was cut to charging box size with an oxy-acetylene blowpipe. This procedure required a great deal of time since each plate had to be preheated in order to initiate the cut. The powder process is now used for quick starting and no preheating time is required. Comparative cutting times on bundles of equal thickness were 15 min for the powder process against 1 hr for standard oxy-acetylene cutting.

**E. D. Gibson:** I would like to hear Mr. Holub discuss the new dispenser which I understand is under development.

**E. M. Holub:** The vibratory type feeder dispenser is still in the development stage. Its main purpose is to give a very exact flow of powder, particularly for thin plate cutting. The powder-flow requirements are more critical on thin material because of the high cutting speeds employed. It can be readily realized how easily the cut may be lost when traveling at speeds of 24 in. per min. Models of this dispenser are now on trial in customers' plants.

**E. D. Gibson:** As I understand it, this is only to be used on cutting. Will it be carried into scarfing?

**E. M. Holub:** It has been tried on scarfing and appears to operate satisfactorily. However, I reiterate that it is still in the development stage.

**Frederick C. Hull:** Would the powder-cutting process work equally well on higher alloyed materials, for example on a heat resistant alloy which contains 37 per cent Ni, 20 per cent Co, 18 per cent Cr, 18 per cent Fe, 3.0 per cent Mo, 2.8 per cent Ti, 0.2 per cent Al, 0.7 per cent Mn, 0.7 per cent Si?

**E. M. Holub:** Yes. Materials containing as high as 95 per cent alloying elements are successfully cut.

**Thomas S. McNeely:** Regarding your discussion of carbide precipitation, in scarfing stainless steel slabs, types 302 and 304, would annealing be an additional operation and an additional cost?

**E. M. Holub:** No. A conditioned slab is reheated for hot-rolling, which operation eliminates any heat-affected zone produced by powder-scarfing.

**Ralph Fair:** On type 310, did I understand you to say that in the powder process the removal is only 3½ per cent?

**E. M. Holub:** I am afraid you misunderstood; for

on any analysis material the percentage removal depends on the depth of the defect.

**Ralph Fair:** Could it be as slow as 3½ per cent?

**E. M. Holub:** We have consistently scarfed with a metal removal as low as 2 per cent. The point that must be borne out is that if a defect is present, the same depth of removal is necessary by grinding as by scarfing.

**Frank A. Snyder:** Is there any advantage in preheating to 400 or 600 F?

**E. M. Holub:** Yes, it will increase the scarfing speed but will result in the formation of a more tenacious slag. If the slag must be entirely removed as has been found in some instances, preheating is disadvantageous. However, should the slag problem be inconsequential, the higher scarfing speeds result in greater economies.

**John H. Vohr:** Is that not inconvenient for the operator?

**E. M. Holub:** It is, and that is why it is not employed to any great extent. The only time preheating is advised is on material subject to cracking, such as any air-hardening steels.

**Frank A. Snyder:** It might be of interest to know about radiagraphing. Formerly when you ground salvaged blooms, they nearly always had to be bloomed the second time and reconditioned. By removing the corners by radiagraphing, they practically all can be rolled down to the finished side.

**Roy P. Tooke:** There is one point we found about this scarfing. Regardless of what your preference is for surface conditioning, it does offer a very easy and economic method of edge conditioning which I did not hear you bring out.

## *Preliminary List of Papers Scheduled for*

# AISE ANNUAL CONVENTION

### CLEVELAND, OHIO — SEPTEMBER 28, 29, 30, OCTOBER 1

Crane Cab Conditioning

Frequency Changers

Developments in Electric Cables for the Steel Industry

Hot Blast Stoves for High Pressure Furnaces

Coking and Blast Furnace Practice at Kaiser

Special Cars For Steel Plant Use

Heating Rates in Reheating Furnaces

Hearth Maintenance in Heating Furnaces

Effect of Oxygen on Refractories in the Basic Open Hearth

Equipment Repairs with Metal Inserts

Water System Maintenance

What the Machine Tool Industry Wants from the Steel Industry

Electrical Equipment for J&L 70 Mph Mill

Review of Runout Table Drives

Improved Flying Shear Drive

Magnetorque A-C Crane Control

Dynamic Hoist Control

Designing Proper Equipment for Extracting Ingots from their Molds

Training Instrument Maintenance Men

Fuel Oil in the Steel Industry

Standby Gases for Emergency Use

High Temperature Lubricants

Centrifugal Purification of Oils in Steel Plants

Bearing Seals

Beam and Channel Roll Design

Plastic Deformation

Analysis of Cold Mill Design

Coal Preparation for Steel Manufacturers

Redesign of Handling Equipment for Heavy Coils

Developments in Sleeve Bearings

Roller Bearings

The Use of Rust Preventives in the Maintenance of Steel Structures

Developments in Butt Weld Tube Mills

Strip Welding

# Modern Methods of Feedwater Conditioning For High Pressure Boiler Plants

By S. D. DISTELHORST, Cochrane Corporation, Philadelphia 32, Pennsylvania

*. . . . final selection of the proper water conditioning process must be made with great care, if optimum results at economical costs are to be obtained . . . .*

▲ THE increasing use by industry of high pressure boilers operating at 900 to 2000 psi has required water conditioning engineers to continually improve on equipment design to meet the exacting requirements of these steam generators. The net results are increased water treatment efficiencies for all pressures. In general, in the consideration of treatment of makeup water for steam generators, emphasis is placed on producing a water having in quality the following general chemical characteristics:

1. Zero hardness.
2. Low total solids.
3. Low concentrations of silica.
4. Low and controllable alkalinities.

## ZERO HARDNESS

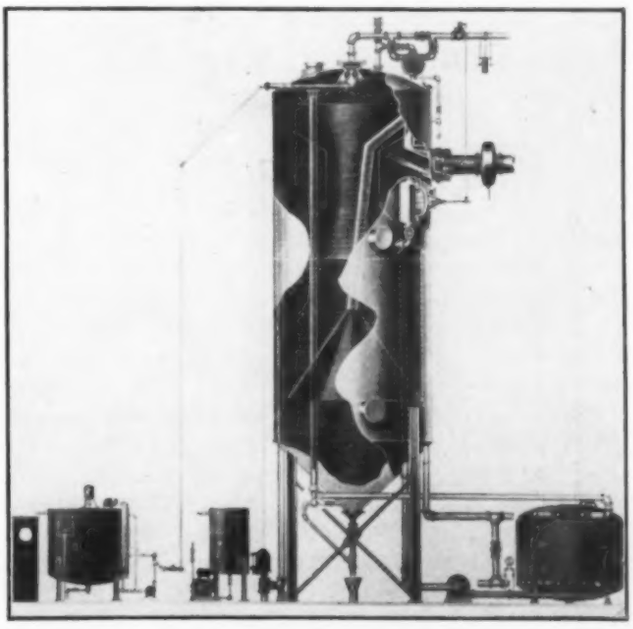
Zero hardness is desired in order to eliminate every possibility of sludge formation in the boiler. A definition of zero hardness goes farther than "zero hardness by the soap test," the general requirement being a hardness of the order of 1 ppm or less by gravimetric analysis irrespective of the type of water conditioning system selected. For example, although a zeolite softener generally delivers an effluent of zero hardness by the soap test, engineers are now specifying zero hardness by titration with three drops of boutron and boudet soap solution rather than the customary four drops. This corresponds to a hardness of the order of 1 ppm or less by gravimetric analysis.

In high pressure generators operating at high ratings, it is often found that continuity of operation is of paramount importance; particularly is this true in the case of topping plants where there is installed a single steam generator and a single turbine. The outage of either the boiler or the turbine will dictate the economy of the combination. Generally speaking, turbogenerators can be operated continuously for years without outage, and the tendency is similarly to operate boilers without internal cleaning for a year or more. In one particular case an industrial plant operating 1400 psi boilers has found it to be economical to install a large water conditioning system to reduce the hardness in condensate initially present to the extent of only 5 ppm. Previous to installation of the water conditioning system, this small amount of hardness was precipitated internally by phosphate, which caused sludge accumulations in the boilers and required their cleaning every six months. With installation of the water conditioning equipment, these same boilers operated continuously for years without internal cleaning and evaporated one million pounds of water per square foot of boiler surface before being shut down for inspection; it was found that cleaning was not necessary.

## LOW TOTAL SOLIDS

With regard to total solids concentration, the desire on the part of engineers at present is the same as heretofore; to provide a makeup water that approaches distilled water as nearly as possible, taking into account the economy of treatment. The low total solids are desirable from the standpoint of minimizing blowdown

**A deaerating hot process softener with a sedimentation-type softener arrangement is shown with electrically controlled chemical feeds at left, sedimentation tank with deaerator, and deaerated water storage compartment, and filter.**



Presented before AISE Annual Spring Conference, Philadelphia, Penn., May 26, 1947

loss and also reducing solids carry-over in the steam so as to alleviate or avoid entirely deposits on turbine blades which interfere with efficiency and capacity of generating equipment.

## SILICA

It is particularly true with high pressure boiler plants operating at pressures of the order of 1200 to 2000 psig that much attention is focused on the concentration of silica in the boiler water.

It is generally conceded that silica, even in low concentrations, is apt to volatilize, be carried over with the steam, and solidify on turbine blades causing loss of capacity and efficiency. This eventually requires costly cleaning or washing with the aid of chemicals, such as caustic soda.

Since all waters contain silica to some degree, often in a quantity that would bring about a prohibitive concentration of silica in the boiler concentrate, much attention is now being directed to the reduction of this silica. For example, specifications are being issued by engineers to water conditioning manufacturers stipulating a maximum silica concentration in boiler concentrates of 5 ppm. This means that some method of silica reduction is mandatory, because generally speaking, even good water supplies will contain silica of approximately 5 ppm on an average, and if a plant is designed on the basis of a 5 or 10 per cent blowdown of the makeup water, then the concentration of silica in the boiler concentrate will be 20 or 10 times, accumulating to an extent of 100 or 50 ppm—far in excess of the stipuated specifications. It is, therefore, quite obvious that some method of silica reduction must be incorporated in the feed water conditioning equipment, and it is rare that this is not given a priority in the conditioning of water for boilers operating at very high pressures.

While silica is not always detrimental from the standpoint of scale formation (being alleviated by the presence of the phosphate radical which permits its accumulation to a fairly high concentration without danger of scale formation), such high quantities of silica are nevertheless detrimental from the standpoint of turbine-blade deposition.

## LOW ALKALINITIES

Although it is very common with low pressure boilers to operate with boiler water alkalinities of 300 to 1000 ppm, the alkalinities permitted in the high pressure steam generators are ordinarily 150 ppm or less. In many cases the alkalinities are not permitted to exceed 100 ppm. This is desirable because low alkalinities produce a sufficiently high pH value to protect the boilers against corrosion, and any reduction in alkalinity over that necessary to prevent corrosion simply adds to the total solids, increases the blowdown schedule and is likely to increase the carry-over tendencies of the boiler concentrate.

While much emphasis has been placed heretofore on the type and extent of alkalinity from the standpoint of boiler plate embrittlement, this is not now the case, undoubtedly due to the general use of welded drums.

All of these chemical properties of a boiler feedwater should be obtained with the minimum investment in equipment and cost of chemical treatment, including

**This package-unit demineralizing system exchanges hardness ions for hydrogen ions which are then removed by acid adsorption and degasification.**

supervision of operation. Obviously, there is no single type apparatus that can meet all of these qualifications best, because of the wide variety of physical and chemical characteristics of water available. However, to meet these objectives there are a number of general types of equipment that are available, which, when properly selected and coordinated, will produce a satisfactory water supply and may even approach distilled water under some conditions.

In general the two major classifications of equipment are as follows:

1. Precipitation type.
2. Ion exchange.

The precipitation type of softener may be utilized singly or in combination with the ion exchange type of unit, and, while the classifications as to the apparatus and combinations of apparatus might involve a long list, it is sufficient for the purpose of this paper to mention three types which are in common usage for the preparation of boiler feed waters:

1. Single and two-stage phosphate hot process water softeners.
2. Carbonaceous or resinous ion exchange zeolite utilizing the sodium cycle or combination of the acid and sodium regenerations.
3. Demineralization with silica ion exchange equipment.

All of these types of softeners have been applied or are contemplated for application to water conditioning for boilers operating at pressures as high as 1400 psig, and one installation is under construction to prepare a large percentage of makeup for boilers operating at 2000 psig.

## HOT PROCESS WATER SOFTENER— SINGLE STAGE UNIT

For waters that are comparatively soft and relatively low in alkalinity, having a hardness less than 50 ppm, the hot process water softener utilizing phosphate as the precipitating reagent has worked out remarkably well. Many units are in service conditioning relatively soft water either initially clear or containing considerable suspended matter, as from surface supplies. To obtain the alkalinity control that is desired, phosphoric

acid is generally recommended as the chemical reagent being introduced into the water supply ahead of the hot process softener, immediately followed by heating and deaeration of the water for discharge of oxygen and carbon dioxide generated by the acid. Following the deaerating process, an alkali, such as caustic soda, is added to raise the pH value to the order of 9.7 to 10 to bring about the optimum environment for the precipitation of calcium phosphate and magnesium hydroxide. It is interesting to note that this process has resulted in a very soft water, not only of zero hardness by the soap test, but generally containing only a fraction of a part per million hardness as determined by quantitative laboratory procedures. On one installation the hardness measurement on a large volume sample of treated water showed a hardness reduction of 0.07 ppm. This process reduces the hardness to such infinitesimal values that the boiler concentrate is generally crystal clear, devoid of every vestage of sludge, and of low alkalinity.

In common with all types of precipitation softeners, the effluent from the sedimentation chambers and filters is saturated with the precipitate under the conditions of operation, so that in a 100 per cent makeup plant, if this water is passed through economizers there may be some tendency for further precipitations of the remanent hardness under the higher temperature conditions, because the calcium phosphate is less soluble at the higher temperatures.

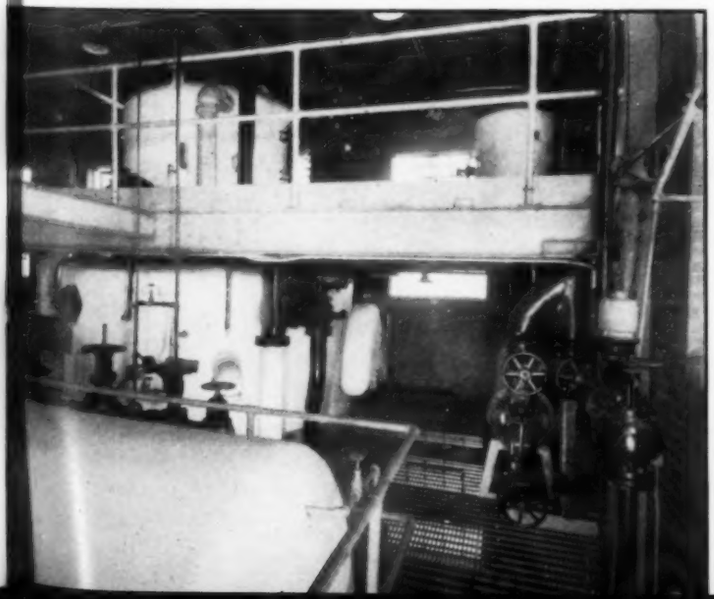
In order to avoid such deposition, treatment of the effluent from such a unit with phosphoric or sulphuric acid to reduce the pH value to the order of 8.5 is generally recommended.

### THE TWO-STAGE SOFTENER

For relatively high hardness waters the phosphate softener is operated in two stages, the bulk of the hardness being first reduced by the cheaper lime and soda ash reagent to approximately 15 to 25 ppm. This water is then delivered to a second sedimentation tank, where the remanent hardness is precipitated by a phosphate reagent, such as disodium phosphate or phosphoric acid. Following this process the water is filtered and then delivered to the boilers. The process of deaeration can follow the softening process or can be made an integral part of the softener sedimentation tank. This type of equipment is particularly advantageous where large quantities of dirty water are available for boiler feed, as the hot process sedimentation tank not only provides for softening by precipitation, but also for coagulation of the suspended matter without the addition of coagulants ordinarily necessary in clarifying plants. The precipitation of the hardness itself is sufficient to coagulate the suspended matter in most water supplies.

With the two-stage softeners, silica can be reduced by the lime and soda reactions if the initial hardness contains an appreciable quantity of magnesium salts; otherwise, magnesium is added by the substitution of dolomitic lime for lime, the former having a sufficient magnesium oxide content to serve the purpose of absorbing silica. To make this magnesium oxide content more effective, sludge is recirculated from the sludge cone to the top of the sedimentation tank, and, in all such cases, equipment is designed to reduce the silica to the order of ½ to 1 ppm. In addition to recirculation of sludge, the sedimentation tanks are equipped with a mechanically-operated stirring mechanism which causes rapid growth of the floc and more effective sedimentation to provide a water of unusual clarity for the second stage, thus avoiding an intermediate step of filtration.

**Shown here is the top deaerating section of a 3-story high deaerating hot process softener at a steel plant in Philadelphia. Low-hardness Delaware River water is treated with phosphate for boiler feed. In the corner at the right is the flash tank recovering 5-psi steam from the boiler blowoff for heating boiler makeup.**



### ZEOLITE SOFTENER

The development of the carbonaceous and the resinous types of ion exchangers has displaced entirely the use of greensand and synthetic silicious zeolites in zeolite water conditioning processes for high pressure boiler plants. The reason is obvious, in that neither the carbonaceous, or the resinous exchangers contain silica, avoiding the possibility of silica pick-up, which is present if the natural or silica-gel types of ion exchangers are used.

In addition to this advantage, these types of materials are such that they can be regenerated with acids without suffering deterioration, making it possible to control alkalinities through the ion exchange process. It is well known that zeolite softeners operate on the basis of exchanging the ions of calcium and magnesium in the water for ion of sodium of the zeolite mineral.

With non-silicious zeolites, regeneration of the material by acid permits exchange of calcium, magnesium and sodium ions in the raw water supply with the equivalent hydrogen ion of the exchanger, so that all of the raw water alkalinity is converted to carbon dioxide, which can be disengaged easily from the water by means of an aerating tower. The sulphates and chlorides are converted to the equivalent quantities of sulphuric and hydrochloric acid, which can be neutralized by the effluent from a sodium exchanger producing sodium bicarbonate from the bicarbonate of calcium and magnesium. Thus, by blending waters from two such treatments alkalinity is regulated at will.

Following this treatment, the water should be deaer-

**Hot process softeners installed in an Ohio River steel plant in 1926 (left) and duplicate installed in 1940 (right).**

ated, then given a supplementary treatment of phosphate to counteract the remanent hardness, which may be of the order of 1 ppm.

A number of high pressure boiler plants have utilized this method of treatment very effectively and it is particularly well-adapted to the treatment of soft, clear waters with low silica concentration. Zeolite treatment, being an ion-exchange process by its very nature does not reduce silica, since the bulk of silica present in water is not in the ionized form and, therefore, is unreactive.

For turbid waters, or waters that are high in hardness, the zeolite process should be preceded by a means of clarification and filtration. If clarification is necessary, it is customary to combine the softening process with clarification in a modern design cold-process apparatus such as the rapid reactor or precipitator, which, by very liberal circulation of sludge, reduce hardness to a relatively low degree with economical use of lime and soda ash. Following this treatment, the remanent hardness is removed by the use of a carbonaceous zeolite softener operated on the sodium cycle.

## DEMINERALIZATION

One of the most recent developments in the water conditioning art is the demineralizing plant for the removal of all ionized materials. This process has been applied more generally to process industries requiring a means of preparing an economical substitute for distilled water. While the demineralization process involves a chemical cost higher than either the precipitation type or the zeolite type softeners, it is nevertheless much more economical than distillation and is finding a very ready market. Thus the pharmaceutical and chemical industries are finding many applications for this method of water conditioning. Obviously, since the aim in condition water is to approach the quality of distilled water, one would expect that the demineralizing process would find acceptance in boiler plants. However, it must be considered that not only is the chemical quality of the water a guide in equipment selection, the cost of the equipment and cost of its operation, and in this category the demineralization process is the most expensive of all methods of water conditioning other than evaporation.

Silica, being un-ionized, passes through the exchanger unchanged. The acid effluent is then passed through an acid adsorber, a synthetic resin, whereby acids other than carbon dioxide are absorbed to produce an effluent for many purposes equivalent to distilled water, containing only silica, a few parts per million of alkalinity, and a trace of chlorides and sulphates. The carbon dioxide is disengaged from the water by passage over a decarbonating tower.

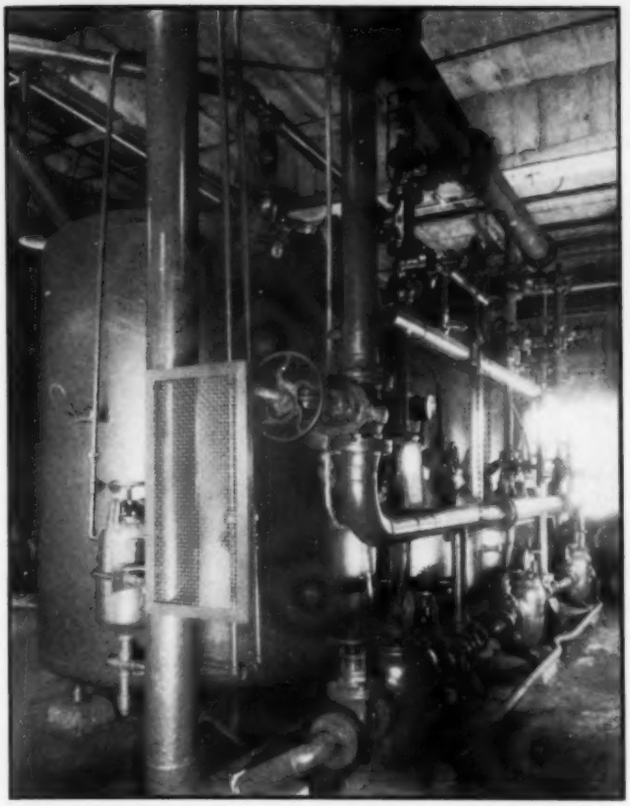
In the previous part of this paper, particular attention was called to silica concentrations. Since the demineralizing process as such does not remove silica, this constituent becomes of extreme importance in connection with the demineralization process, because the water is low in total solids, permitting low blowdown, so that even small quantities of silica in the raw water supply may accumulate to relatively large quantities in the boiler concentrate. For example, with demineralized water blowdown requirements may be reduced to the order of 1 per cent, whereby the boiler concentrate will be 100 times as concentrated as the treated makeup water, and if the raw water contains only 2 ppm of silica, then the silica concentration would build up to 200 ppm, which obviously is over the permissible limit. Therefore the demineralizing process must be supplemented by means of silica removal, by either of two methods:

1. By adsorption using magnesium oxide and caustic soda.
2. By treatment with hydrofluoric acid or its equivalent and subsequent ion exchange.

The first method involves the installation of a hot process softener, following the ion exchange units, in which magnesium oxide is introduced into the sedimentation tank along with a small amount of caustic soda to give the proper pH value. With recirculation of the magnesium hydroxide sludge, silica can be reduced to low quantities. This water then should, of course, be followed by filtration then supplementary phosphate treatment to the boilers. It is obvious that such an arrangement involves the extensive combination of equipment, so that this system is not generally recommended in view of the more economical procedure of softening and removal of silica in the single sedimentation tank through the use of a phosphate-type hot process softener.

Still in the stage of development is the method of removing silica by ion exchange which can be accomplished in the demineralizing process by modification to standard equipment. There are a number of methods which can be followed, but the principal one is the introduction to the raw water supply of sodium fluoride which, when subject to the action of the cation exchanger, is converted to hydrofluoric acid. The hydrofluoric acid passes along with the other acids to the anion exchanger unit and is adsorbed. As such, it has the ability to react with silica in solution, forming fluosilic acid, $H_2SiF_6$. Thus the silica is adsorbed. Experimental plants have indicated that silica can be reduced by this means to the order of 0.25 ppm.

This process, however, complicates considerably, the



**Triple-unit sodium-regenerated carbonaceous zeolite softener installed in a war-time Duluth steel plant.**

process requiring the adsorber to be regenerated first by an acid salt in order to discharge the silica from the adsorber bed. The use of an alkali at this stage would precipitate the silica as $SiO_2$. Following the initial regeneration of the adsorber, secondary regeneration is undertaken, using an alkali, such as soda ash or caustic soda, for discharge of the remaining adsorbed acids, such as sulphuric and hydrochloric acid. After rinsing, the unit is again ready for acid adsorption and silica removal.

This process of silica removal is rather expensive and, coupled with the complete demineralization process, the chemical costs involved are far greater than the zeolite or the hot process softener which is the principal objection to the general application of this process for boiler feed service. However, a 500 gpm unit is to be placed into service shortly in Texas in which well water of high silica and mineral content is to be completely demineralized for boiler feed makeup. The plant is not selected on the basis of economy, but chiefly for the purpose of research development of the process and the resins.

A second plant is now scheduled to be constructed having a capacity of 2000 gallons per minute to prepare Lake Huron water for 1400 psig boilers.

It is quite apparent that the available processes require rather critical examination and analysis of the conditions for which they may be contemplated, and the final selection of the proper water conditioning process must be made with infinite care if the optimum results at the most economical costs are to be obtained.

The objectives sought can be obtained by any one of the three general processes discussed, but the principal influence in final selection is the capital investment and the cost for operation of each. It would be folly to select equipment on any basis that would ignore these fundamentals, and it would be impossible to lay down any fast rule as to where this process or that process may be best applied; that must be left to the judgment of one experienced in this art.

# DISCUSSION


**PRESENTED BY**

**F. C. SCHOEN, Plant Engineer, The Midvale Company, Nicetown, Philadelphia, Pennsylvania**

**S. D. DISTELHORST, Cochrane Corporation, Philadelphia, Pennsylvania**

**M. B. ANTRIM, Electrical Engineer, Lukens Steel Company, Coatesville, Pennsylvania**


**F. C. Schoen:** In a unit developed for the armed services, the necessary heat to maintain the operation, once they have started operation, is supplied by the motor, or engine, driving the vacuum pump, and one of its purposes in the past was to obtain drinking water. It does have a remarkably high heat balance and some of the things that you see, lead you to believe it costs only a few cents an hour to run, even in the larger sizes.

**S. D. Distelhorst:** I have two more things I was thinking about that I wanted to bring up. In the hot process, generally the reaction time is about an hour, and it is usually operated on five or ten pound steam, which would sterilize the water. We had the question come up in the case of an installation about six months ago, in a Rocky Mountain mine that was quite isolated. They wanted to know about the health qualities, the potability of the water. It was tested by the State Board of Health, I believe in Wyoming, and found more than satisfactory from the health point of view.

Another thing, I looked at a job at your plant, Mr. Schoen, recently and the Midvale Company draws their water from the Delaware River. I think it is an emergency supply, and that actually most of your water is drawn from the Schuylkill, and your own wells, which gives a considerable difference in raw water characteristics. In some of the larger plants, that becomes quite a factor, because you have to have flexibility to tie in these different systems, together with all these other factors. The problem is to take water, maybe from three or four different supplies from time to time, and have the equipment simple enough to operate, and still complex enough to take care of all these varying raw water constituents. That is another reason for being particularly careful in selecting the water conditioning equipment.

**M. B. Antrim:** I note from experience there are very many peculiar things that occur when you lower the pressure on water. I remember once we were running an experiment on the triple point of water, and with the water at room temperature, under a bell jar from which air was evacuated, the water began to boil. As the pressure was lowered still more, ice began to form on the boiling water and we then had steam, water and ice all at the same temperature. Upon restoring normal air pressure and quickly removing the bell jar, the ice could be picked out of the water and you might say that it was really "hot ice."

# Resistance Welding

***. . . . the economical operation of many continuous processes in the steel industry is dependent on successfully welding strip to form units capable of relatively long runs . . . .***

▲ THE most common use for resistance welding in the steel industry is for welding the ends of strip steel for continuous pickling and continuous cold rolling.

For continuous mill lines, where the weld is to be cut out after pickling, a lap-type joint is used. These joints can be spot welded, roll spot welded, or seam welded, with comparatively simple and inexpensive resistance welders.

The simplest welding machine for this type of application is the gun welder. This type of welder is used on very thin gage strips, not exceeding approximately 24 in. in width, and where it is desired to bring the welder to the work. This type of equipment, see Figure 1, originally designed for use in the automotive industry, is generally considered too light in construction for the steel industry, though it has been used successfully in the smaller mills.

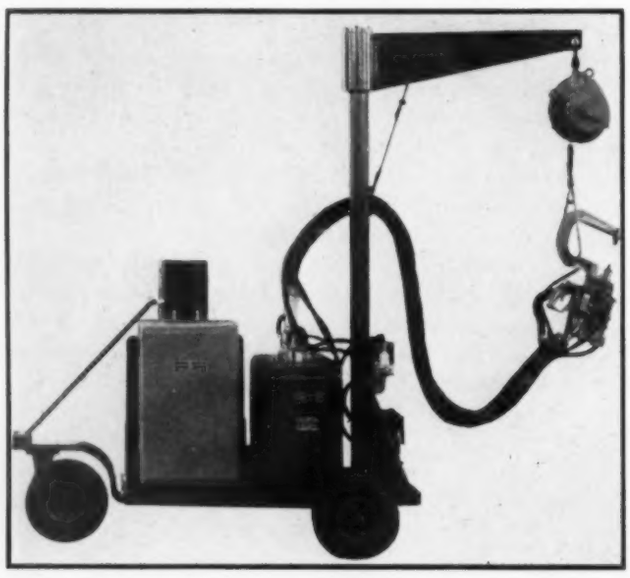
As width and gage of the stock increase, several different welding machines have been designed to suit the particular applications. One type machine, the multi-spot welder, shown in Figure 2, consists primarily of a number of spot welding units mounted to a bridge type member extending across the width of the stock, the number of welding heads depending on the width of the strip to be welded. These welding units are fired all at once or in sequence, depending on whether the welder is of the multi-transformer, hydro-matic, or ultra-speed design. With the multi-transformer design, all welds are made simultaneously, while with the hydro-matic and ultra-speed types, the welds are performed in sequence.

The many types and designs of multi-spot welder used in various branches of the steel industry, each designed to meet the customers' particular demands, are too numerous to cover in this short article.

A recent application of the spot welder, which is receiving ever more widespread application, uses two movable spot welding heads on a traveling carriage. This type of machine, shown in Figure 3, is used in stainless steel annealing lines for making lap welds in order to hold the strips together as they travel progressively through the furnace, the quenching tanks and the pickling line. The strip is then rewound in coils and the weld area is removed. In this case, large coils are not built up, but the spot welding is used simply to take advantage of continuous annealing, quenching and pickling.

Presented before AISE Annual Spring Conference, Philadelphia, Pennsylvania, May 26, 1947.

**Figure 1 — The simplest resistance welder for seam or spot welding lap joints is the gun welder.**



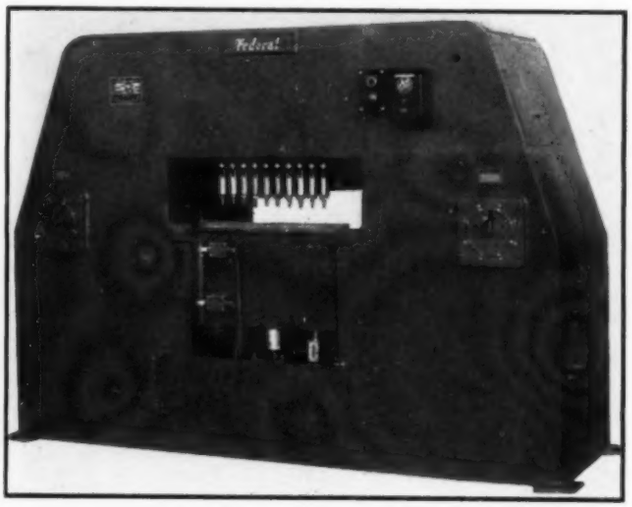



**Figure 2 — The 10 point ultra-speed spot welder is especially designed to handle strip.**

By far the most practical and most popular type of welding machine for joining the ends of strip steel by the lap method, is the traveling head series seam welding machine. See Figure 4. This type welder is not an adaptation of a standard welding machine to strip steel use, but is designed expressly for steel mill application and is, therefore, of a sufficiently rugged design and construction to meet the critical demands of the steel industry. This type of equipment is installed directly in the strip line and is manufactured in various sizes to cover the specific demands of its own particular application.

With this type of welding equipment, the two rows of welds are made in series, and therefore the width of the strip will not affect the current characteristics in any way due to the fact that the strip does not extend into

# ...the Steel Industry

By O. H. GRIFFITH
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the magnetic throat of the welding machine. The welding electrodes of this type machine are of the wheel type, and are mounted on spindles to permit them to rotate as they move across the steel strip. These wheels are carried on individual arms operated by air cylinders, thus assuring the proper welding pressure on each welding electrode independently of the other. The arms are

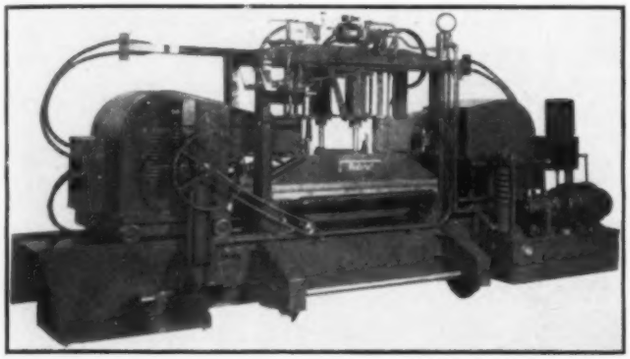


**Figure 3 — The double spot welder is used in stainless steel annealing lines.**

mounted on a movable carriage which is furnished with anti-friction rolls and travels on steel rails when moving across the strip. The carriage, which contains the welding transformer and heat regulator, is moved across the steel strip by means of a motor-driven screw through a variable-speed drive arrangement, thus permitting the speed of travel to be varied within the limits of the control units. The welding electrodes are spaced on approximately 6-in. centers, with a clamping beam for holding the strip located between them. This beam is constructed of a non-ferrous material so as not to choke the welding current and to prevent the beam from getting hot during the welding operation. The previously described welding machines are for use where the strip does not have to travel through rolls, and where the welded areas are cut out after processing.

Where the strip is to be processed by cold-rolling, it is necessary to weld the two ends of the strip by the flash-butt weld method. There are numerous sizes and styles of flash-butt welding machines in use in the strip steel industry. The size and design of the welding machines depend on the width and thickness of the stock to be welded.

For comparatively light-gage stock and narrow width

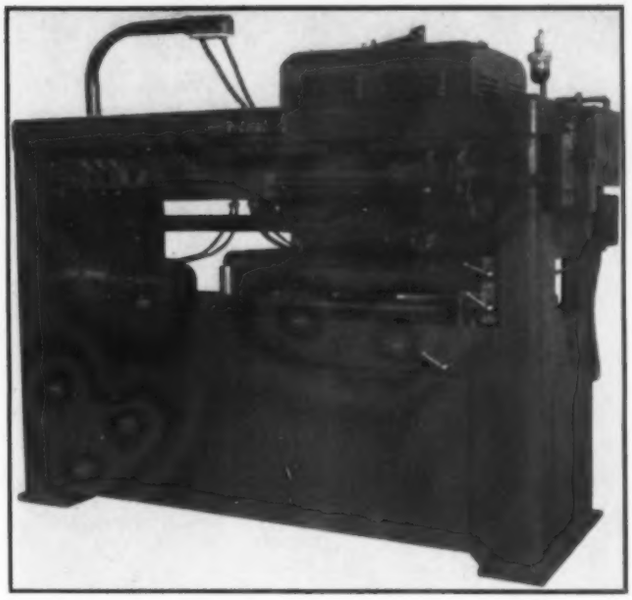


**Figure 4 — The traveling head series seam welder was developed for steel mill use.**

of strip, a standard-design flash welding machine, see Figure 5, can be used. These machines are generally equipped with air-operated, vertical-type clamping units, of either the alligator-type or the direct slide-action type. The travel of the movable platen is controlled by an upset cam driven by a motor through a suitable gear-reduction unit. These welders can be supplied with wheels riding on steel tracks so that the welding machine can be moved into the strip line to make the weld and then return out of the line while the strip continues through the various processes.

As the width of the strip increases to the extent that it is no longer practical to move the flash welder into the strip line, a specially-designed flash welding machine is used. This type welder is designed to be permanently installed in the strip line. With this type of equipment, the trailing end of the one strip is clamped into the stationary dies of the welding machine, and the leading end of the following strip is clamped in the movable dies, by either air or hydraulically-operated cylinders through suitable toggle links. The ends of the stock can be sheared either before coming to the welding machine, or the welding machine can be supplied with a rotary-type shear unit, see Figure 6, which is moved through the welder at right angles to the strip line, thus shearing the ends of the trailing strip and the end of the leading strip simultaneously. This assures perfect alinement of the parts as they are brought together for flash welding. After the shearing operation, the shear unit moves out of the welding machine and the movable platen moves forward until the ends of the strip are brought together and the flash period of the weld commences. The movement of the platen on this type of welding equipment is usually governed and controlled by two or more hydraulic cylinders through suitable hydraulic equipment. The design of the equipment is such that the movement of the platen is accurately controlled and easily and quickly adjusted for various widths and thicknesses of stock. As the weld takes place, a gripping unit clamps

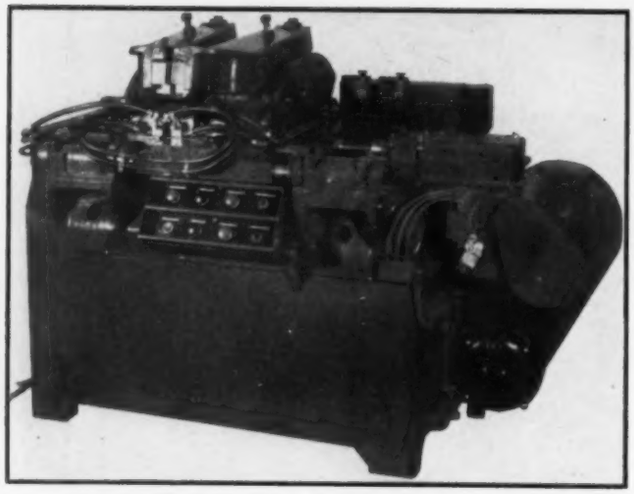


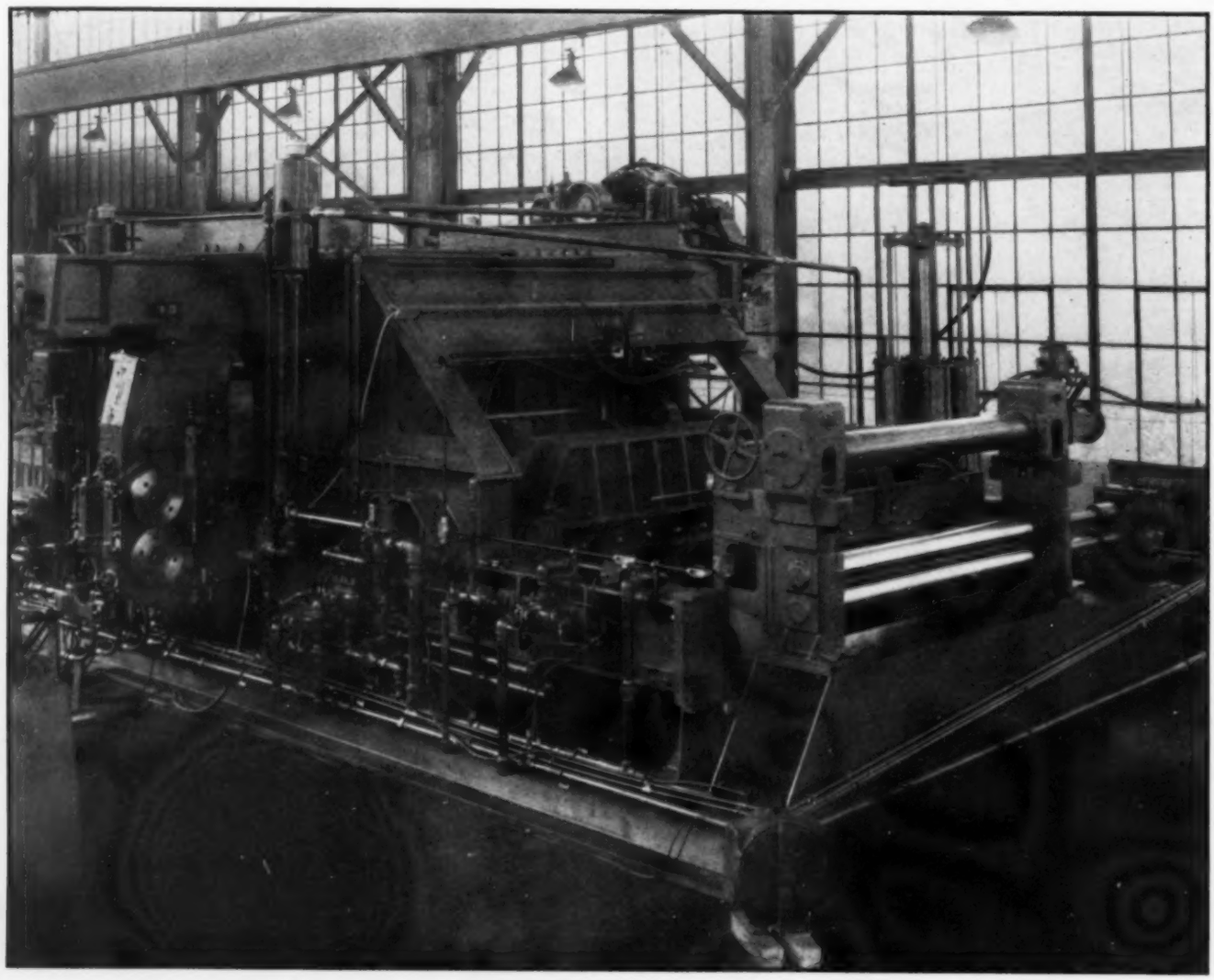
**Figure 5 — Standard flash welding machines are applicable for butt-welding narrow, light gage strip.**

the strip and pulls the work through a plow-type stripper at the completion of the weld. The plow-type stripper removes the flash from the top and bottom of the strip as well as the two edges. In place of the plow-type stripper, a draw-type stripping unit, designed to be mounted in the strip line, may be substituted.

For positioning the steel strips prior to the welding operation, this type of welding equipment is furnished with air-operated, motor-driven-type pinch roll units, on both the leading and trailing side of the welder. While the cost of this type of equipment is much greater than the equipment used for spot welding the two ends of the strip steel together, it has advantages that are readily recognized by steel manufacturers; the welding time, or down time of the strip line, is much shorter than the spot-welding method and the strip can be considered as continuous. After pickling, coils of any desired size can be wound, or if the steel is to be run through a continuous cold-rolling mill it can be done without damage to the rolling equipment.

This same type of equipment is used almost exclusively for the welding of the ends of skelp, to be used in the manufacture of steel tubing. See Figure 7. Skelp welding equipment is similar in operation to that described above, with the exception that the ends of the skelp have to be sheared before arriving at the welding station.

**Figure 6 — This photograph shows a special strip, flash welder with pinch rolls and rotary type shear.**



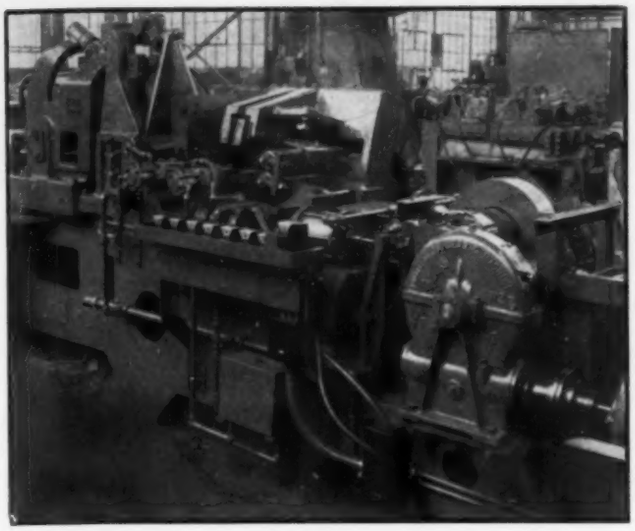


**Figure 7 — Special flash welders are used almost exclusively for welding skelp.**

Resistance welding has been advancing rapidly in the strip steel industry because it is the fastest, best and cheapest method of joining strip steel. This advancement has been brought about by the continued cooperation of the steel producers and fabricators and the resistance welding machine manufacturers. The welding machine manufacturers are looking forward to greater strides and advancement in the future through the cooperation of engineering, experimental, metallurgical and research departments. While the use of resistance welding in the strip steel industry is confined primarily at the present time to mild steel, stainless steel, and to some extent to silicon steel, we are, however, looking forward to the day when resistance welding machines will be used in the manufacture of special alloy steels.

# DISCUSSION

**PRESENTED BY**


**A. J. FISHER, Assistant Chief Engineer of Construction, Bethlehem Steel Company, Bethlehem, Pennsylvania**

**O. H. GRIFFITH, Welding Engineer, The Federal Machine and Welder Company, Warren, Ohio**

**W. E. GRAINGER, Assistant General Manager, Bethlehem Steel Company, Sparrows Point, Maryland**

**M. D. STONE, Manager, Development Department, United Engineering and Foundry Company, Pittsburgh, Pennsylvania**

**FREEMAN H. DYKE, Assistant General Manager, Wheeling Steel Corporation, Steubenville, Ohio**


**A. J. Fisher:** Is there any advantage in annealing strip before cold rolling?

**O. H. Griffith:** That, I think, is a mill operation question. However, if you are referring to the weld area, and if the strip is mild steel then there would be no advantage in annealing the strip.

**W. E. Grainger:** I have found that there is one condition resulting from butt welding a strip that gives considerable trouble in actual practice, which you did not refer to, and I am just wondering if perhaps you have any experience, or know of anything that is being done about this particular difficulty? In building up coils, after the pickling by butt flash welding, the metal is hardened, and in passing through the mill, there is a tendency for the strip to break at the weld, which causes considerable slow-up in operation. Either the mill is actually slowed up, or the strip breaks, resulting in loss of production. Is anything being done, or could anything be done, to anneal, or otherwise heat treat the weld quickly at the time, or immediately following the welding operation, to put the steel into condition so it would pass through the mill at the same speed as the other parts of the strip?

**O. H. Griffith:** Yes, the welding machines can be furnished with an annealing feature. This has not been done in the large strip welders in the larger widths. This is usually done by providing an additional tap on the welding transformer. The stock is released from the clamping units, and the movable platen is retracted, and then clamped on the strip again, and then through a number of pulsations, the current is turned on at a lower secondary voltage than used for the welding, and the stock annealed in this manner.

**W. E. Grainger:** Are you putting out such equipment, or making provisions for any equipment on any installations that you know of?

**O. H. Griffith:** Annealing equipment has been put on a number of installations. I do not recall any particular installations in mill equipment as yet, but it has been put on a number of flash welding machines.

**Member:** Will you discuss undercutting the weld slightly with a draw type trimmer?

**O. H. Griffith:** That is being done in some cases. It is, of course, impossible with the plow type stripper. When using a plow type stripper, the trimming, or the shearing, is usually done on a slight bias, usually three or four degrees across the strip, rather than being 90 degrees or perpendicular to the edge of the strip.

**M. D. Stone:** Do you know if you have very much trouble with breakage of silicon steel, resistance spot welded, in going through high speed processing lines?

**O. H. Griffith:** From the information that I have, we do not experience too much trouble. We have built a great number of the simple type spot welding machines.

**M. D. Stone:** Are they meeting with acceptance for high silicon steel?

**O. H. Griffith:** Yes.

**Freeman H. Dyke:** I would just like to add to this discussion that in my opinion the problems involved in rolling tin plate on high speed tandem mills is totally different from rolling heavier gage auto body. We have no trouble with 26 gage and heavier. On tin plate rolled down to 0.006 and 0.007 in. the problem is different, particularly with steel containing phosphorus and nitrogen. Recent developments in controls and heavier mills have simplified the problem to a great extent, but the welding and trimming of the weld is still a most important feature of the operation.

# Design, Construction and Lubrication of Mill Couplings and Spindles

By WILLIAM L. STOVER
Mechanical Engineer
Mesta Machine Company
Pittsburgh, Pennsylvania

*. . . . couplings for rolling mill service require proper and careful design, adequate lubrication, and protection from dirt to obtain maximum life and minimum maintenance . . . .*

▲ THE selection of the proper couplings and spindles is of prime importance in the design of any rolling mill. Excessive maintenance or breakdown of these parts seriously affects the operation of the mills and reduces their efficiency. It is necessary, therefore, that sufficient engineering time be given to the study and design of these couplings and spindles to insure maximum effectiveness in operation.

Many items must be considered in the design of these parts, namely:

1. Minimum roll centers which limits the outside diameter of couplings.
2. The torque to be transmitted during normal operation, the overload the driving motor is capable of developing, and the inertia of the drive which governs the size of the spindle body.
3. The lift of the rolls, or the distance between centers of a twin motor drive, which affects the angularity and thus the length of the spindles.
4. The selection of the proper breaking point as a protection for the mill in cases of excessive loads due to excessive drafts, or rolling material of lower than design temperature.
5. Lubrication of the couplings which affect the maintenance and replacement costs.

The designers of the early mills met these conditions with the muff type coupling and spindle as shown on Figure 1. Two types were developed and are still being used with good success on many types of mills at the present time. The first type of spindle, as shown at the top, is used when the driving and driven member are practically always in line as in the case of a bottom roll drive. The wabbler of this spindle has straight sides. The other type spindle, known as the vibrating spindle, has curved surfaces at the end of the wabbler, and is used when there is any appreciable angularity between the driving and driven members. The torque is transmitted to and from the spindle through the coupling box shown at the bottom. When completely assembled, the coupling box is half on the roll wabbler and half on the spindle wabbler. It is held in place by a shoulder on the roll, and by wooden blocks in the wabbler on the spindle, which in turn are held in place with wire or strap iron around the outside of the blocks. The wabbler on the spindle is long enough to allow the coupling box to slide entirely on the spindle when the wood blocks are removed.

One of the chief advantages of the muff couplings and spindles is their simplicity. They are cast steel, of 0.35 to 0.45 per cent carbon with 70,000 psi ultimate strength, and are cast smooth and to size. The only machining required, therefore, is on the body of the spindle for the supporting spindle bearing. The coupling box is also cast smooth and to size with no subsequent machine work required. The outside diameter of the coupling box is cast of such size that extra heavy loads will cause the box to fail before any other part of the mill. This part is the cheapest and easiest to replace. The outside diameter of the coupling box should be approximately 1.5 times the diameter of the spindle body.

The muff coupling is lubricated solely by a coating of heavy graphite grease. There is little or no dirt protection; consequently the lubrication is not too effective, resulting in undue wear if the angularity is very great. These spindles have been used at angles of 15 degrees, but it was found that they would wear out in two to three weeks time and were deemed impractical. An angle of 10 degrees under moderate loads, or 5 degrees or less for heavy loads, is considered about the best operating conditions for this type of coupling.

One of the biggest disadvantages of the muff coupling is the terrific noise caused by the large clearances inherent in this type of coupling. Especially is this true on reversing service where there is constant pounding at every change of direction.

Studies were made to find a coupling with quieter operation, and one with bearing metal between the sliding members. The result was the development of the universal coupling and spindle. Figure 2 shows the gen-

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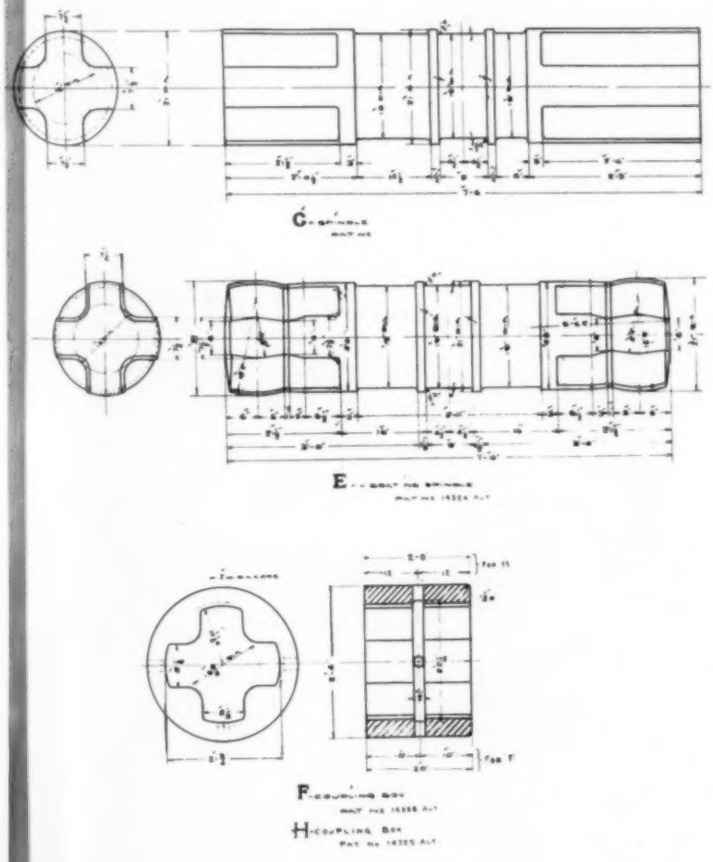
eral form of the universal coupling. It is rather difficult to compute the exact sizes required for these couplings. The load to be transmitted is sometimes not too well established, and the precise manner in which the torque is transmitted through the coupling itself is also not too well defined. We have learned much from the couplings in actual service, and from a study of these the designer is able to proportion the proper size of the coupling and spindle to meet his need. Figure 2 gives the relative proportions of the component parts of the universal coupling, based on the spindle body diameter and also on the outside diameter of the jaw. These average figures were gathered from a wide range of couplings and spindles actually in use, consequently they may vary slightly from the sizes of any particular installation.

On the right of Figure 2 is the spindle with the jaw half coupling. In the center is the bearing assembly with two bearing segments, or slippers as they are often called, on the bearing pin, ready for assembly in the jaw half coupling. On the left is the spade half coupling ready to enter between the bearing segments. All sliding movement is made against the bearing segments, which can be replaced easily when worn. The bearing pin is made in two types. One is a straight pin, which enters through a hole in the jaw half coupling, then through the first bearing segment, a hole in the spade, and the second bearing segment. The pin is made slightly shorter than the outside diameter of the bearing segment. Countersunk plugs hold the pin in place. This type is used when it is desired to positively hold the

**Figure 1 — The muff type coupling and spindle was used in early mills.**



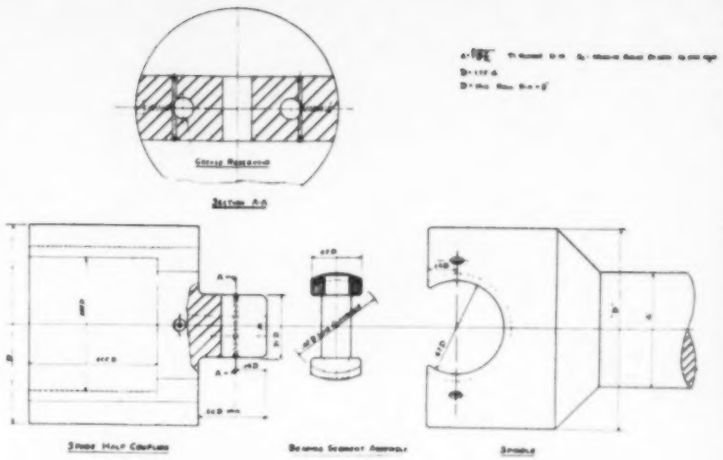


**Figure 2 — Typical proportions for the universal coupling and spindle are shown in these sketches.**

spindle and coupling from separating as when changing rolls. The other type bearing pin is the shoulder type as shown with the bearing segments. The larger diameter of the body holds the bearing segments apart and is used when it is desired to shift the spade in and out of the jaw without interference from the bearing segments. The spade is made with an open slot for this type of bearing pin. The bearing segment assembly is installed in the jaw by entering one segment and then rotating the assembly until both segments are in place, thus requiring no fasteners to hold the segments in the jaw.

One manufacturer uses a different type pin and bearing segment. Instead of a straight pin, a through bolt is used, which passes through the jaw half coupling and the bearing segments, with the head and nut countersunk on the outside diameter of the coupling. The bolt holds the segments in place by a hole in the bearing segments, which is elongated to allow them to rock in the jaw if the spindle runs at an angle to the coupling.

Materials used in the manufacture of the couplings and spindles are selected for their strength, toughness, and wearing qualities. The spindles are usually made of forged steel of 0.35 to 0.45 carbon, annealed to 70,000 psi ultimate strength. Where extra strength is required, spindles are forged from alloy steels and annealed to much higher ultimate strengths. The half couplings are either of forged steel or cast steel of similar requirements as the spindle. The bearing segments are made from either a high grade of cast aluminum bronze, or of a composition material. The life of the segments depends upon their wear and resulting clearances.

Very little has been done until recently in the way of dirt protection on the mill spindles due to the very close clearances between the couplings at minimum roll centers. Some operators have tried a canvas boot around the joint but this has not been universally accepted. On recent cold mill spindles, covers were designed which were both oil tight and dirt proof. The spindles and couplings were made of alloy steels which allowed the outside diameter of the couplings to be made slightly smaller to make room for the cover. The bearing segments are covered by a bath of oil which rotates with the couplings keeping the segments completely lubri-

cated at all times. Where the universal coupling is used singly as in a leading coupling, adequate covers are used, which will be described later.

Shown in section "AA" of Figure 2 is the method of lubricating the coupling. From a grease fitting on the outside of the coupling, the lubricant is fed into the 2 in. diameter reservoirs. Drilled into the outer edge of the reservoirs are holes leading to the sliding surfaces of the coupling. The holes are plugged at these surfaces with a countersunk pipe plug in which has been drilled a 1/8 in. vent hole. As the coupling gains speed of rotation, small amounts of lubricant are forced centrifugally to the sliding surfaces. The vent hole in the pipe plug meters the flow. If the bearing segment has been chipped with the proper grease grooves, the lubricant will be uniformally distributed even against moderate loads. It is not necessary for a system of this kind to lubricate the spindles during the heavy loads since they

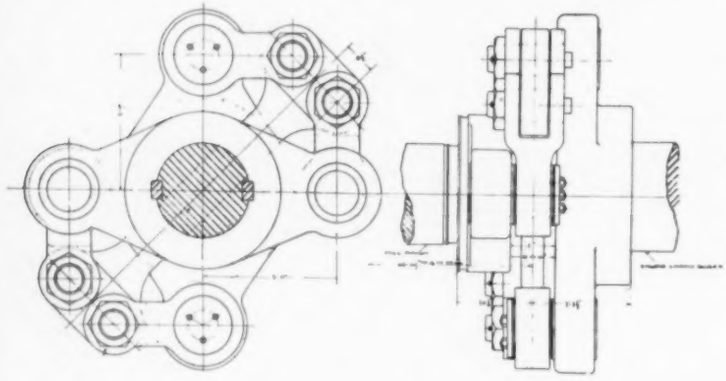


**Figure 3 — Leading couplings and spindles transmit power from the motor to the pinion stand.**

are intermittent. A good coating of lubricant is forced on the spindle during no load intervals, when the rolls are idling, and this carries them over the heavy load period.

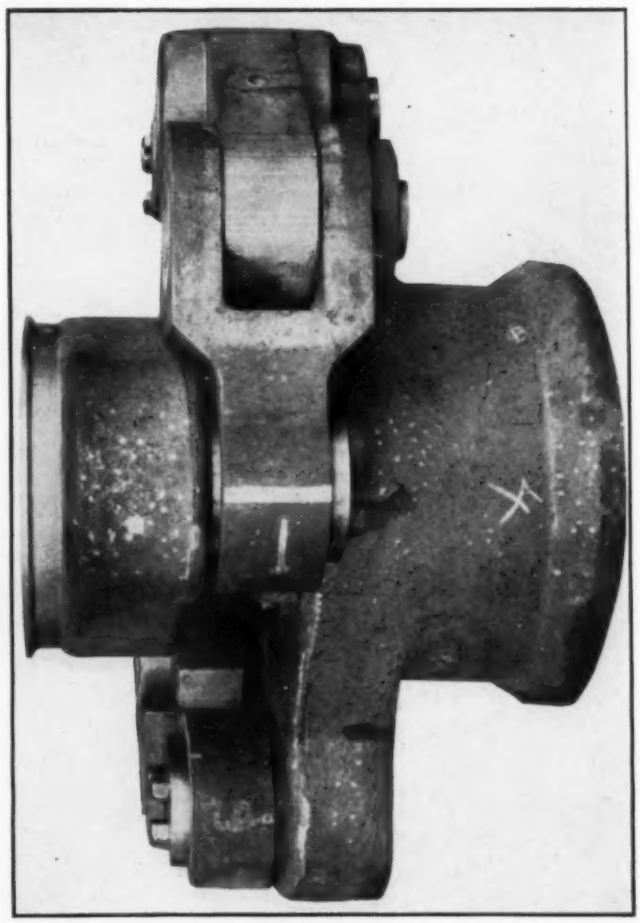
## LEADING COUPLINGS AND SPINDLES

Special couplings and spindles were developed to transmit the power from the driving engine or motor to the pinion stand. These became known as leading couplings and spindles. Julian Kennedy developed one of the early forms which bears his name. Figure 3 illustrates this coupling. The torque is transmitted through a system of links and an equalizing bar which compensates for any parallel misalinement of the motor and pinion stand. It does not compensate for any angularity between the driving motor and pinion stand, however, which is one of its chief disadvantages. The links and equalizing bar have bronze bushings as bearings which are grease lubricated through holes in the pins. With this coupling, the motor and pinion stand must be close together so that each can directly support its hub of the coupling. A floating shaft cannot be used with this coupling unless a rigid bearing support is used at the coupling end of the shaft. Figure 4 shows a shop view of the coupling assembly with the motor end at the right.

Several types of commercial couplings are available of heavy construction to withstand the large torque and shock of the modern mills. The universal type coupling which has been successfully adapted to use as a leading coupling, is shown in Figure 5. The spindle is in the form of a cross with flats extending on both sides of the body. The coupling half on the pinion or motor shaft contains the jaw in which ride the bearing segments. The half coupling on the motor shaft may be made in two parts which are flanged, keyed, and bolted together. One part contains the jaw of the coupling. The other part, which is shrunk on the motor shaft, has the thrust bearing for the motor. With this assembly, if the jaw half coupling breaks, it is not necessary to remove the coupling from the motor shaft, with possible injury to the shaft, but instead, a new half coupling is simply bolted in place and operation of the mill resumed. A stationary oil and dirt tight split cover completely encloses the coupling. The top half of the cover is designed for easy removal to inspect the bearing segments and for replacement of these segments when necessary. Cast integral with the cover is a double set of lubricating ribs. The flanged portion of the motor half coupling, which runs in a bath of oil, splashes some of the oil on the ribs, which flows down to the lower tip of the ribs and drips directly on the bearing segments, completely lubricating them.

While most operators prefer to have the various elements sufficiently strong to withstand peak loads, some shear pin leading spindles as shown on Figure 6 have been used. The spindle is made in two identical pieces with a flange on one end and a spade on the other end

**Figure 4 — A photograph of the coupling sketched in Figure 3 is here shown. Motor end is to the right.**



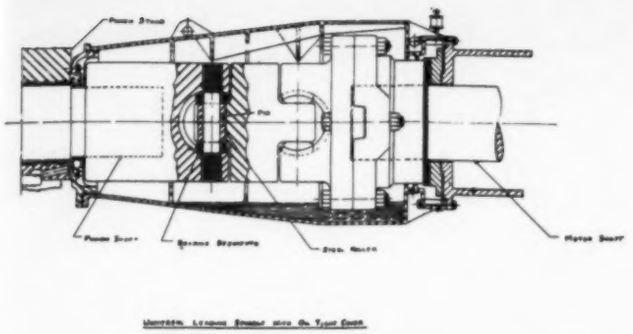


Figure 5 — The universal coupling is also used as a leading coupling.

of each piece. The flanges are clamped together, and eight equally spaced holes are bored and reamed. Hardened steel bushings are then pressed into each hole of each flange. Only two pins or bolts are used, which are placed in holes diametrically opposite each other. The body of the pins is grooved slightly at the joint between the two spindle flanges to insure that the pin will shear straight across its diameter, instead of the usual 45 degree shear plane. It is difficult sometimes to get the breaking point of the pins determined to a degree that will not cause too many annoying shutdowns. The two bolt heads and the two threaded ends are each wired together to prevent accidents if the bolts should be thrown clear of the bolt holes. If one pair of holes become worn or damaged, another pair may be used when the new bolts are replaced.

Each flanged spindle half is bored at the longitudinal axis for a 9 in. diameter pin which is long enough to extend well into both spindle halves. If the shear bolts break, this pin prevents the spindle halves from flying apart, and causing damage to machinery or accidents to personnel.

The entire weight of the spindle is supported on rollers, which in turn is supported by springs in the spindle carrier. The springs can be adjusted to maintain the correct tension to carry the weight of the spindle.

Short spindles with shear pins have recently been developed to fit inside the cover as shown on Figure 5.

Exceptionally short leading spindles are in use as shown in Figure 7 in which the spindle is made from a steel flat of sufficient thickness to transmit the torque. An oil and dirt tight cover is made to completely surround the lead spindle and bearing segments and rotates with them. The bath of oil surrounding the spindle and bearings also rotates with them, consequently, there is no churning effect and no heating of the oil. Large couplings of this type have been made with 13 in. centers between the bearing segments.

In another well known coupling, the power is transmitted through a double row of splines running in an oil bath. This particular type of coupling is especially suited for floating shaft service, since no bearing stand for the floating shaft is required except in cases of extra long shafts. This coupling is also used as a leading coupling. The power is transmitted through a series of steel grid springs which are laid in the grooves of the driving and driven hubs. These grid springs absorb some of the shock loads of the rolling operation.

## SLABBING-BLOOMING MILL COUPLINGS

The slabbing-blooming mill presents perhaps the most severe service of any present day rolling mill. Its heavy shock loads due to large drafts and reversing service demand the best of spindle design and material. Since it is necessary to shift the spindles before roll

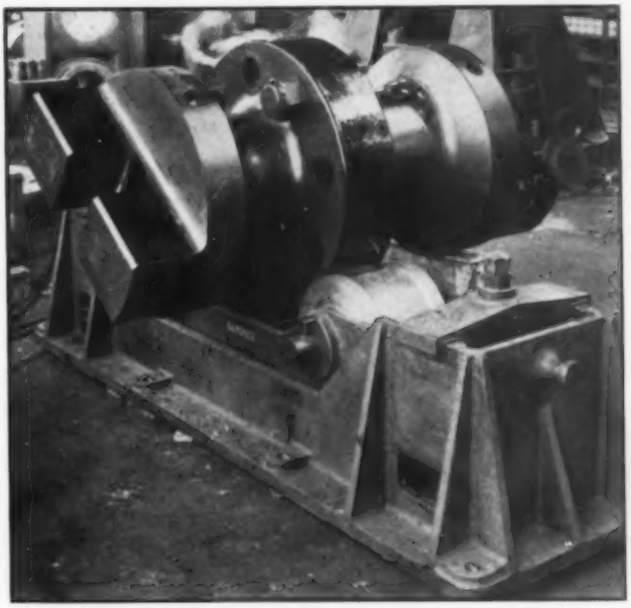


Figure 6 — Two bolts on this coupling act as shear pins for overloads.

changing, one important difference in the fundamental design of universal spindles must be incorporated on the slabbing-blooming mill design. The spindle must be shifted enough so that the jaw of the spindle will clear the spade of the roll, to allow the roll to be raised vertically without interference. Figure 8 shows the long spade on the roll and the deep notch in the jaw of the spindle to allow for this shifting. A stronger and more expensive design has a rib in the center of the notch which is slightly thinner than the width of the slot in the spade. This rib strengthens the jaw against the spreading force without interfering with its operation. Because the spade is lengthened, it must be made heavier and the jaw larger in diameter than in the general universal coupling, to transmit the torque. Consequently the ratio between the spindle body and the outside diameter of the coupling as given in Figure 2 will not be true for this type of coupling. Notice in Figure 8 the position of the bearing segments and pin, which shows how the segments with the shoulder type pin can be rotated into place. Also notice the bevel on both the spade and bearing segments which facilitates entering the spade during the shifting of the spindles.

Before shifting the spindles, the counterbalance system is locked in a predetermined position which will make the spindles nearly horizontal. The shifting is done either by a crane, or by means of motor operated screws which move the spindles toward the pinion stand. Each spindle has its own motor and shifting mechanism. The motors and operating mechanism are mounted on the pinion stand with rods extending to

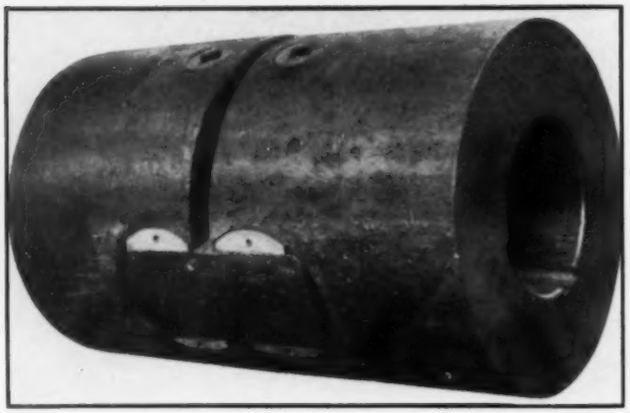


**Figure 7 — Shown here is a very short leading spindle.**

either the levers supporting the pinion end of the spindle carrier bars, or the spindle carrier bearings. The shifting is done by two 25 hp, 460 rpm, compound-wound mill type motors. Figure 9 shows a shop setup of the bottom spindle with its spindle bearing, carrier bars, and part of the shifting mechanism. The spindle carrier bearings slide on the stationary carrier bars during the shifting operation. Figure 10 shows the complete setup of the mill with the spindles and carrier bars in place. We can also see part of the shifting mechanism for the top spindle which in this case shifts the carrier bars with the spindle. After the new rolls are in place, the motor operated screw again shifts the spindle and spindle carriers into place. Since slabbing mill rolls are usually made of a special cast steel whose strength and wearing properties are similar to the properties required for couplings, the roll end spade is made an integral part of the roll.

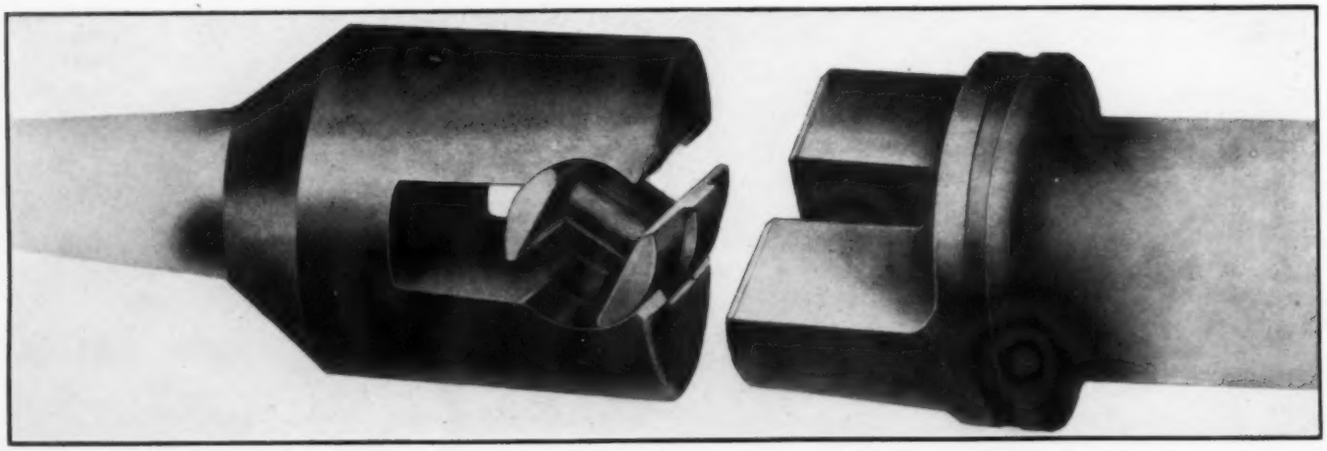
The slabbing mill spindle is made of two parts consisting of the spindle with an integral jaw half coupling for the pinion end, and a separate half coupling for the roll end which is shrunk on the spindle. Since it is the weakest part of the assembly between the driving motor and the roll, unless a shear pin leading spindle is used, most spindle failures appear at this point. The broken member can be removed from the spindle and a new coupling half shrunk on. It has been found, in some cases, that if only one half of the jaw breaks the remaining jaw exerts a sufficient bending movement to cause the spindle to bend at the nearest bearing support.

The modern slabbing-blooming mill with its high lift for edging passes, requires very long spindles. It has been found that for this type of service about 10 degrees is the maximum allowable angle of inclination of mill spindle. With this limit, mill spindles of about 27 ft-0 in. long between centers of bearing segment have been used. These spindles are carried in two babbitted bearings on 10 ft-6 in. centers and supported by the spindle carrier bars. The mill side of the top carrier bars is carried by the roll balance system whether weight balanced or hydraulically balanced, and with the balance system compensated for the extra load on the spindle side. The mill end of the bottom carrier bars is supported by a frame spanning the shoeplates. Either the spindle carrier bearings or the pinion end of the carrier bars are supported by springs, which may be adjusted to make the spindle carrier bearings the right height to carry the full weight of the spindles. Thus, the bearing segments carry only the torque load and none of the dead weight of the spindles.

## PLATE MILL COUPLINGS

A very interesting arrangement of spindles was used on a recent plate mill drive in the Pittsburgh district. It consisted of two 5000-hp reversing motors, one driving the top roll with the other driving the bottom roll. The best arrangement of the motors for such a twin drive is to have the top roll motor above and behind the bottom roll motor. The elevation of the two motors was placed, such, that the top roll did not take all of the angularity, but some was shared by the bottom spindle. The maximum angle measured from the horizontal was about 4 degrees since maximum power would be delivered at this angle, in contrast to the 10 degrees of the slabbing mill, where maximum torque is not expected during the edging pass. Spindles 36 ft-0 in. long be-

**Figure 8 — The most difficult coupling service requirements in rolling mills are in blooming and slabbing mills.**



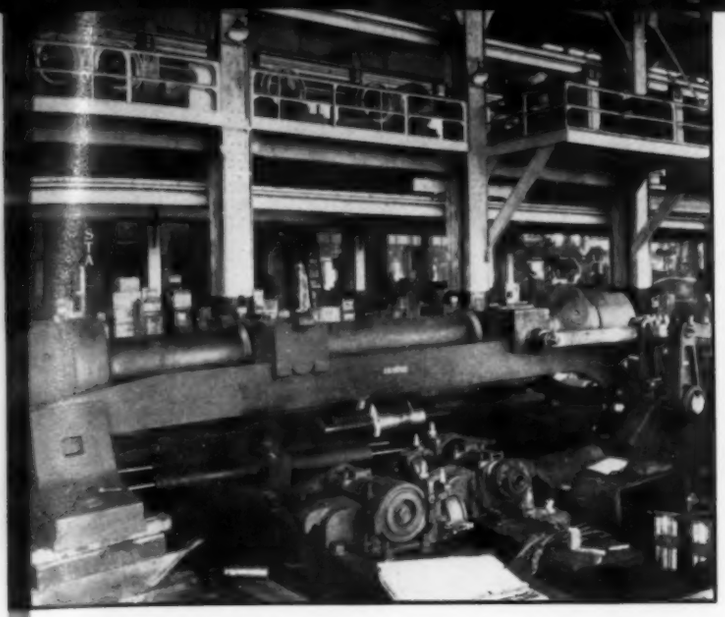


**Figure 9 — Shop setup of bottom spindle for mill shown in Figure 10.**

tween centers of the bearing segments were necessary to maintain this 4 degree angle. The spindle body is 22 in. diameter with the integral jaw coupling half on the motor side 48 in. outside diameter. The jaw half coupling on the mill side is tapered with 35 in. diameter over the jaw, and 40 in. diameter over the body. The coupling half was tapered toward the roll end to allow the roll centers to come closer together, allowing for dressing of the work rolls. Both spindles are of the same length. Connecting the top spindle to the motor is a shaft extension, rigidly supported at the motor and at the spindle end.

The mill spindles are carried by babbitted bearings supported on rolled steel spindle carriers. The bearings are spring mounted in the bearing support. The motor end of the carrier bars is supported by rigid brackets. The mill ends are supported by separate hydraulic systems for each of the spindles. With the separate system, each spindle can be controlled separately and may be locked at any desired height for roll changing.

Both spades are made with an open slot for easy removal from the spindle, with the spindle being held laterally by the shoulder on spindle bearing journal acting against the carrier bearing. Spindle shifters on this mill are not needed since no vertical lift of the rolls is required before withdrawing them.

A semi-automatic lubricating system is used on the spindles of this mill. Each end of the spindle has a 4 in. diameter bore, 32 in. deep on its longitudinal axis. Into this bore is inserted a spring base, a long rather weak coil spring, an oil tight plunger and a vent plug. The lubricant is forced in the 4 in. diameter chamber ahead of the plunger, compressing the spring and filling the chamber. The spring exerts a pressure against the plunger and the lubricant, forcing it out gradually through a series of drilled holes and directly onto the bearing segments. As the spindle rotates in one direction, one side of the bearing segment will be tight against the spindle and the other side loose. The lubricant naturally will flow into the loose side as the path of least resistance. But since this is reversing service, the tight and loose side of the bearing segment also reverse and the other end of the bearing segment becomes lubricated. When the lubricator chamber becomes empty, it is necessary to again fill the chamber manually.

## HOT STRIP MILL COUPLINGS

The mill spindles of the modern strip mill are of the standard universal type. The angularity is very slight, coming almost entirely from dressing down the work rolls. The spindles may be quite short then, ranging from 5 to 6 feet in length. Each spindle is supported by a single bearing, carried by the spindle carrier fastened to the pinion stand. The bottom spindle is spring balanced and may be adjusted to maintain the proper height during roll changing. The top roll is weight balanced which can be blocked in any desired position. The spade on the roll half coupling has an open slot so that the roll may be removed without removing pin through bearing segments. The spade on the pinion end has a hole through which passes the bearing segment pin and keeps the spindle from moving laterally when the roll is changed. The carrier bearings are a composition material which is water lubricated.

It is interesting to note that all the stands of the hot strip mill use the universal type spindles with the exception of the spreading stand. Here momentary high torques delivered from the inertia of motor and flywheel are so great that the universal coupling, limited by the work roll diameter, could not carry the load. Muff couplings are used which could transmit the torque and still be small enough to allow for adequate roll dressing.

## BAR, BILLET, MERCHANT, STRUCTURAL AND SHEET MILL COUPLINGS

Before the development of the continuous mills for rolling bars, billets and structural shapes, the mills for rolling these products were laid out in line on one common shoeplate. One motor and pinion stand drove many mill stands, through spindles connecting the rolls of the first stand to the rolls of the second stand and so on. A great many mills of this type are being used today very effectively—some of very recent construction. Some different problems arise in the design of spindles for these mills. When it is desired to change rolls the entire stand is removed and replaced with another stand with the new rolls. This means that the spindles must easily be shifted from the rolls far enough to clear the housings as they are lifted and removed.

Universal couplings and spindles may be used between the pinion stand and first mill stand with adequate spindle shifters to withdraw the spindle from the rolls. Spindle carriers must be used to support the spindles.

Between the stands, the muff coupling is found most practical. When the stands are very close together as in the smaller mills, there are no spindle carriers used, so the spindles are removed entirely when changing stands. On larger mills, carriers are used in which case the muffs are shifted entirely on the spindles and the stand removed with the spindles remaining in carriers.

The universal coupling is the coupling most generally

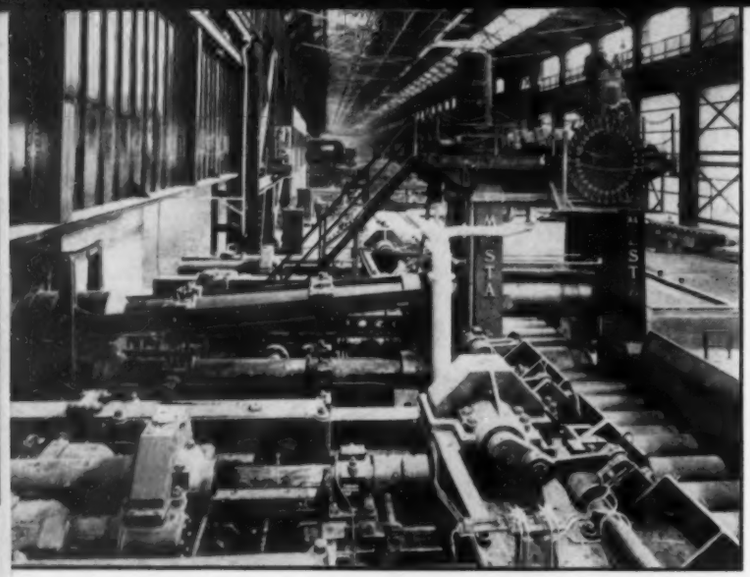


**Figure 10 — Complete setup of slabbing mill showing spindles and carrier bars.**

used, where applicable, on all types of modern day mills. There are some features, however, which still continue to require much thought and development. Foremost of these is lubrication. Some systems, already mentioned in this paper, are used effectively, but still require manually lubrication at stated intervals. On modern mills with complete motor operated, fully automatic, oil and grease systems, one or two points requiring manual attention often are overlooked for long periods. This can result in undue wear and higher maintenance cost.

Along the same line of proper lubrication is adequate dirt protection. The solution to this problem is difficult due to the limitations of the size of coupling, but these things should be kept in mind in the development of future couplings and spindles.

# DISCUSSION

**PRESENTED BY**


**L. F. COFFIN, Superintendent, Mechanical Department, Bethlehem Steel Company, Sparrows Point, Baltimore 19, Maryland**

**R. F. LAVETTE, Superintendent, 44-, 36- and 32-Inch Mills, Republic Steel Corporation, Chicago, Illinois**

**W. L. STOVER, Mechanical Engineer, Mesta Machine Company, Pittsburgh, Pennsylvania**

**T. R. MOXLEY, Superintendent of Maintenance, Wheeling Steel Corporation, Steubenville, Ohio**

**M. D. STONE, Manager, Development Department, United Engineering and Foundry Company, Pittsburgh 22, Pennsylvania**


**L. F. Coffin:** Universal spindles and couplings are a continuous headache for maintenance men, and a really first class universal coupling has yet to be designed. Engineers and designers should exert their efforts to this end so that costs and delays from this source may be reduced.

**R. F. Lavette:** The semi-automatic lubrication system mentioned in connection with the plate mill at Pittsburgh is interesting. I am wondering whether it has had further application to the large mills, and how successfully it has worked out?

**W. L. Stover:** Up to the present time, that one plate mill is the only mill where that type of lubricator has been used. We are more or less trying it out before applying it anywhere else.

**T. R. Moxley:** Mr. Coffin and ourselves follow the same procedure with reference to repairing spindles. Mr. Coffin rebores the spindles, when they become worn in the seats, putting in oversized segments. That, I think, is standard practice in every steel mill in the country; as well as welding them up, and using them all over again. I think we all do that, and it has worked out very profitably.

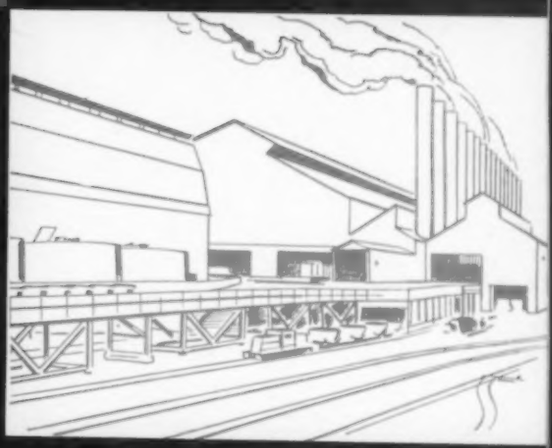
One thing I would like to mention with reference to spindle segments, or slippers as they are commonly called. We have our own brass foundry, where we make all our segments for the spindles for all the mills we have, and we have effected considerable saving, after a continued practice of trial and error in manufacturing these segments cast to size in the foundry. We find we get longer life in these segments, than in those that we machine. We also went back to aluminum bronze. We have effected a considerable saving in casting these segments to size, and it works out very well. We thought we were going too far in the cold mill, but it works out there, as well as in the slower speed mills.

With reference to the lubrication of spindles, especially in the cold mill where you have high speed, naturally the centrifugal action of the spindle is high, so we found we much prefer oil to grease, because these spindles do get warm.

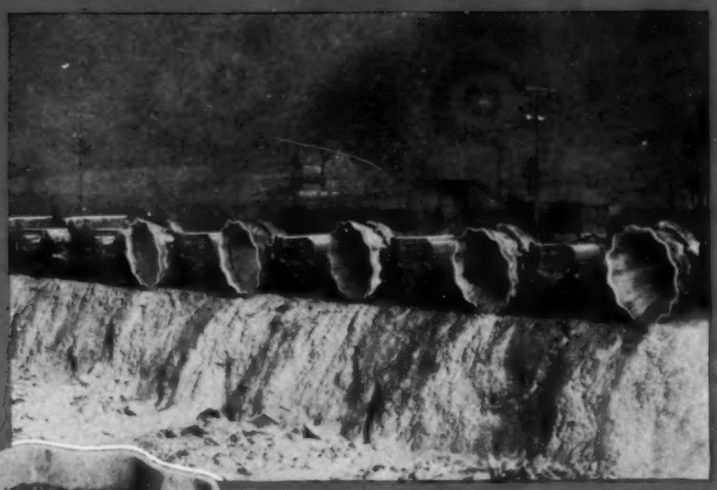
We have built on the spindles of the high speed tandem mills suitable covers for the mill spindles and have made them as dustproof as possible; and in the bottom of these covers we have installed a tank and a circulating pump. We use an oil of 900 viscosity, and continually recirculate this lubricant. It is sprayed on the segments of the spindles on each end, then naturally the force of the centrifugal action will throw the oil out on to the sides, and then it drops into the tank again, and in this way, you do not overheat the oil, and you keep out a lot of the dirt. In this way we have been able to prolong the life of our spindle segments considerably, and we find it is much more effective than grease.

**M. D. Stone:** There might be one point I could add with respect to design of universal spindles, and that is with respect to the assembly of the slipper in the coupling half. One design we have used rather successfully, is to make it in the form of a large screw thread, and screw it into the coupling half. It has an advantage in that it allows you to design a strong coupling half, stronger than if you had to assemble it through the end and rotate it. The slight angle that is involved in screwing the part in, does not interfere with the coupling operation.

# The modern open hearth



# Johnston Corrugated Cinder Pot Performance Key to Slag Handling Economy



View showing Johnston Corrugated Cinder Pots at slag dump, Weirton District

Close-up of Johnston Corrugated Cinder Pot

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# OPEN HEARTH PLANTS

RECENT McKEE ACTIVITIES have included work on open-hearth furnaces in both domestic and foreign locations. Contracts for these projects ranged from supervision of rebuilding to design, engineering and construction of complete plants ready for operation. The total annual production capacity of the twenty-five units involved is in excess of two million tons.

The same quality of engineering which has made the McKee organization the leader in blast-furnace design and construction is apparent in the superior design and efficient construction of McKee-built open-hearth plants.

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ARTHUR G. McKEE & COMPANY
*Engineers and Contractors • Established 1905*
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FOR THE IRON AND STEEL AND PETROLEUM REFINING INDUSTRIES

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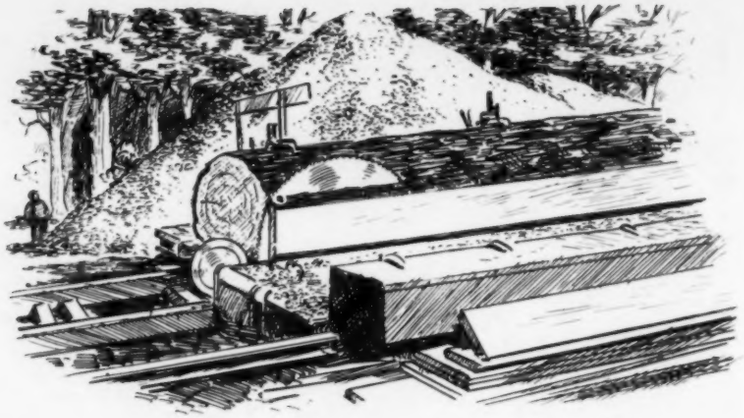


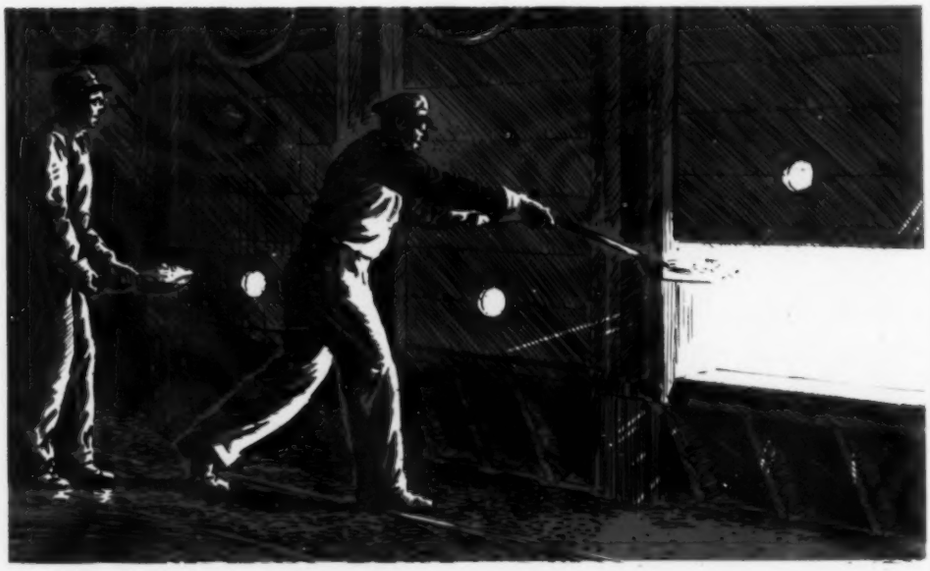
# SAWDUST FOR OPEN HEARTH BOTTOMS?

"SURE, he could make bottom out of sawdust." Every old timer recognizes this remark as a compliment to the skill of an open hearth operator.

Today, the demands on the steelmaker's time are so great that he finds it difficult to supervise open hearth bottom installations or personally to direct maintenance and fettling practice.

So the busy steel operator welcomes the assistance offered by our service engineers. The Basic Engineer has the viewpoint of the operating man. His own steelmaking experience qualifies him to cooperate in a practical manner on your problems relating to the production of quality steel at lower cost. He is always at your service.

Think of the Basic Engineer as your "special assistant superintendent" on hearth refractories, and call upon him whenever he can help you.



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REPRESENTATIVES OF GATHMANN INGOT MOLD DESIGN

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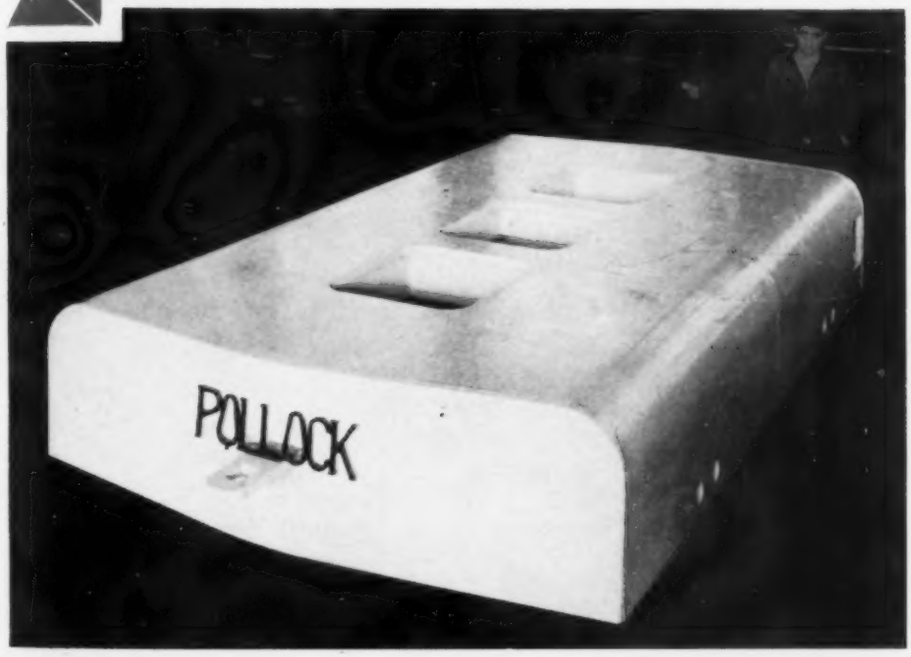
Urgent need for open hearth ladles to handle bigger heats without increasing the load on cranes and buildings presented a problem for ladle builders to solve. Early in 1932 The William B. Pollock Company met this problem by designing and building all rolled steel ladles of welded construction, much lighter in weight but as strong, or stronger, than the heavy ladles of old design that they replaced. The Pollock Company will be glad to send you a list of 311 welded ladles built during the past 13 years, many of which were put in service long before other ladle builders had recognized welded construction. We will welcome the opportunity to help you with your ladle problems.

## OPEN HEARTH EQUIPMENT




When ordering ingot cars the next time why not specify welded plate construction? Whether they be small or large, narrow or standard gauge, Pollock cars of rolled steel will give you complete satisfaction. With ten years experience in making steel mill cars of welded steel, The William B. Pollock Company is qualified to offer you designs that will prove best for your particular use. The ingot car shown on this page is built for a capacity of 141,000 pounds, is standard railroad gauge, measures 13′ 3″ long, 7′ 10″ wide, and is equipped with roller bearings.

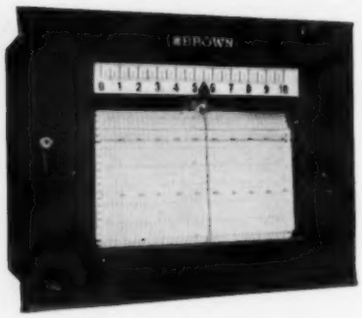
**The WILLIAM B. POLLOCK COMPANY**

YOUNGSTOWN, OHIO

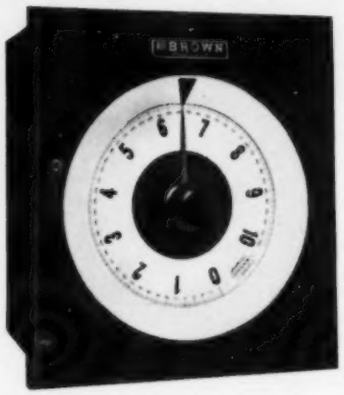
STEEL PLATE CONSTRUCTION • ENGINEERS - FABRICATORS - ERECTORS

# IMPROVE OPEN HEARTH OPERATIONS

ElectroniK Circular Chart Controller




ElectroniK Strip Chart Recorder and Electric Controller

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## BROWN ELECTRONIK POTENTIOMETERS

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Measuring bath temperature by air purge Photronic cell method.

**FOR**

**BATH TEMPERATURE MEASUREMENTS**
Air Purge or Platinum Thermocouple Methods

**ROOF TEMPERATURE CONTROL**
Back Wall, Roof Block or Front Wall

**CHECKER TEMPERATURE CONDITIONS**
and Reversal Systems

**FLAME CHARACTER — AIR PREHEAT**
for Heating Efficiency

Measuring bath temperature by platinum thermocouple method.

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***CONTROL FOR***

**OIL, TAR, PITCH, GAS and AIR FLOWS**
Control Systems for Regenerative Firing

**OXYGEN MEASUREMENTS**
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Indicating Control Flow Meter

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## REDUCE
## OPERATING COSTS

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**279 OF THESE CARS NOW SERVE THE STEEL INDUSTRY**

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on charging side

LADLE CRANES
on pouring side

# E C & M CONTROL Excels

FLOOR TYPE CHARGER

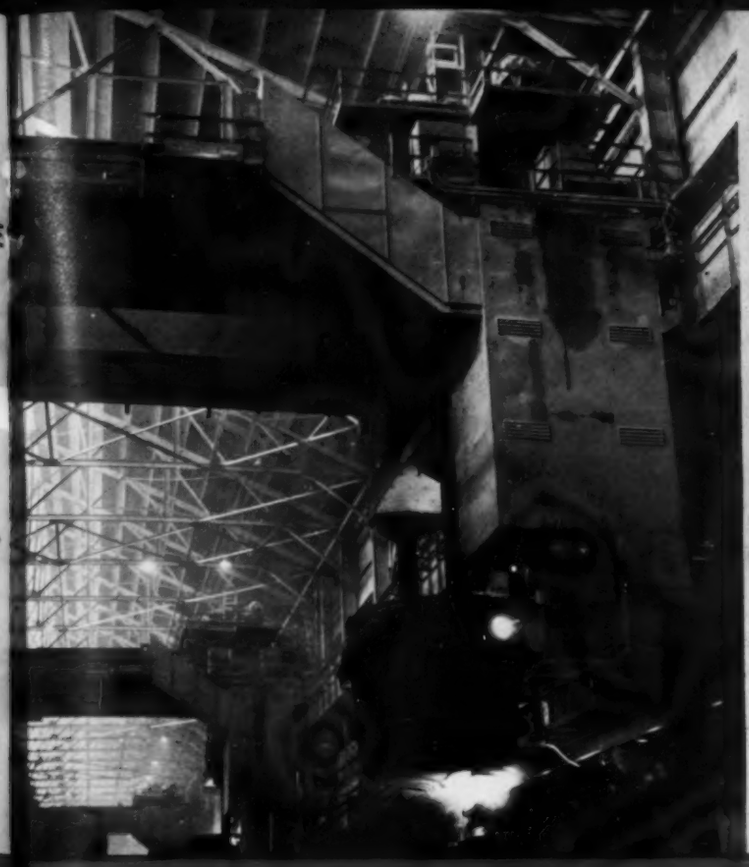
Other open hearth machines for which E C & M Control is well suited, include:

1. Dolomite Charging Machines
2. Jib Cranes for Spout Handling
3. Tilting-type Furnaces
4. Bessemer Converters
5. Doors, Valves, etc.

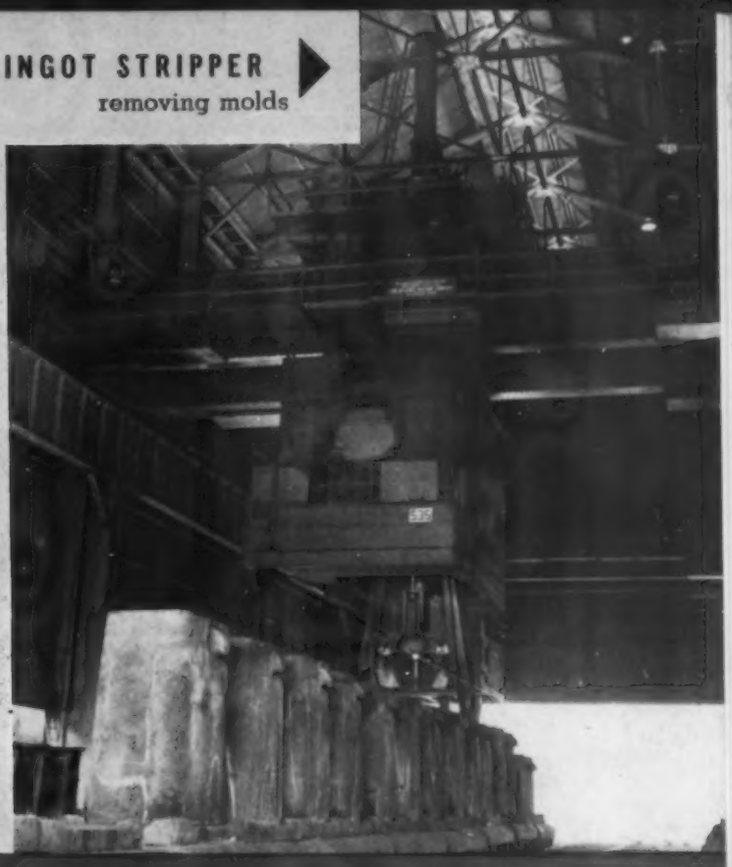
**When buying Open Hearth equipment, specify EC&M Control,**

SOAKING PIT CRANES

STOCKYARD SCRAP CRANES



**INGOT STRIPPER** removing molds



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1. TIME-CURRENT ACCELERATION
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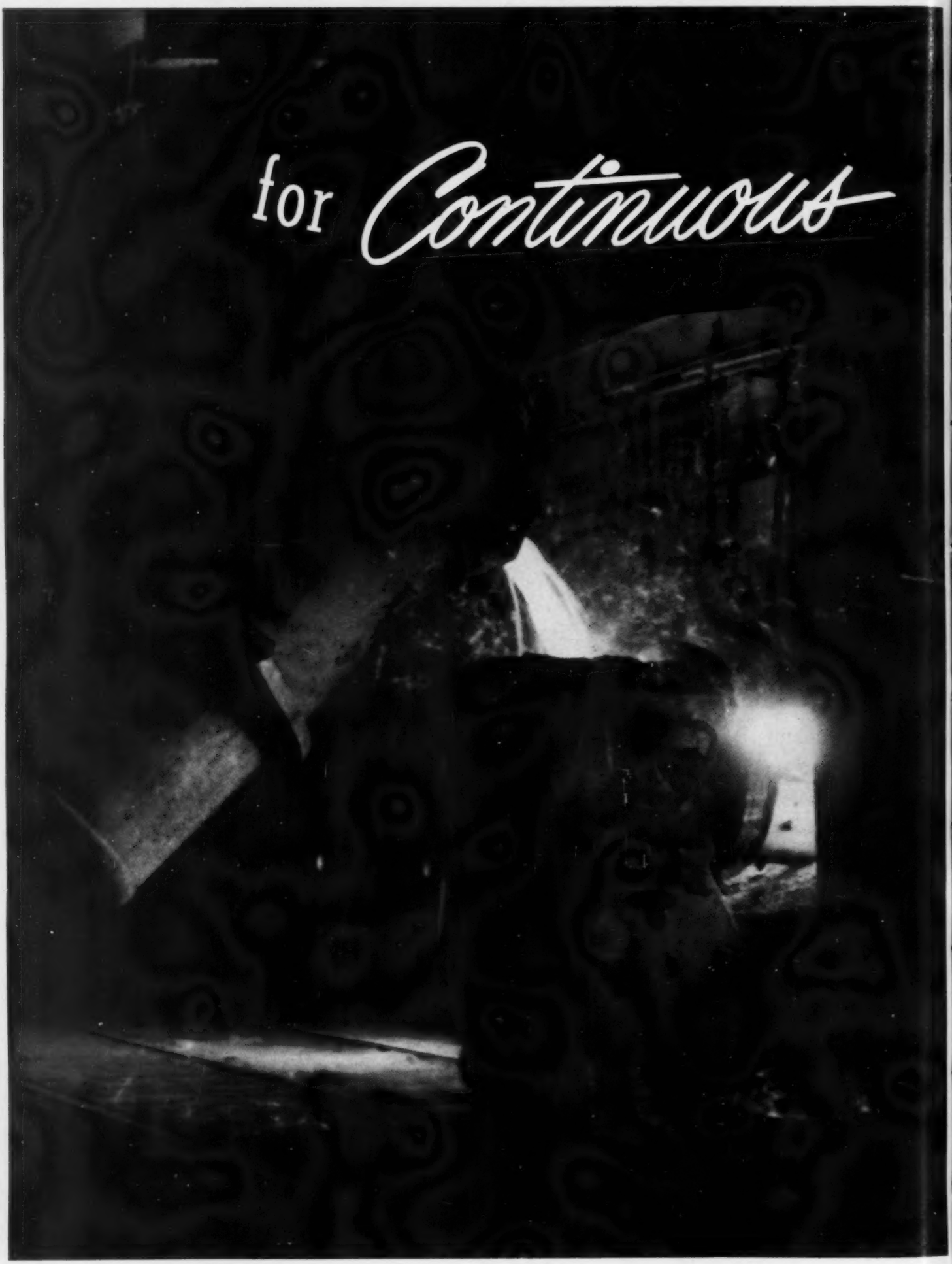
**POURING METAL** from the hot metal Mixer. EC&M control for the tilt motion of the mixer gives 100% safety and dependability for this operation.


for Continuous

# Harbison-Walker Refractories

## have all the qualities you need!

For every refractories application in the open hearth furnace, Harbison-Walker products provide the specialized qualities needed to give longer life, continuous service and peak tonnage.

It is not by chance that experienced open hearth operators prefer Harbison-Walker materials for roofs, walls and bottoms. Among the outstanding Harbison-Walker refractories made especially for open hearth service are these: **STAR,** high duty silica brick; **VEGA,** super-duty silica brick; **METALKASE,** metal encased magnesite brick; **CHROMEX,** unburned chrome-magnesite brick; **CHROMEX B,** hard-burned chrome-magnesite brick; **MAGNAMIX,** 80% magnesia ramming mixture; **DEAD BURNED MAGNESITE GRAINS.** Developed through engineering research, tested in actual service, Harbison-Walker refractories have gained their leadership through outstanding performance.

With manufacturing plants in ten states and sales offices in principal cities throughout the country, we are in a particularly advantageous position to serve industry.

There is a Harbison-Walker product for every refractory requirement. Our Technical Department will assist you in choosing the brand and type of refractory best suited for your particular application.

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## built with REFRACTORY CONCRETE

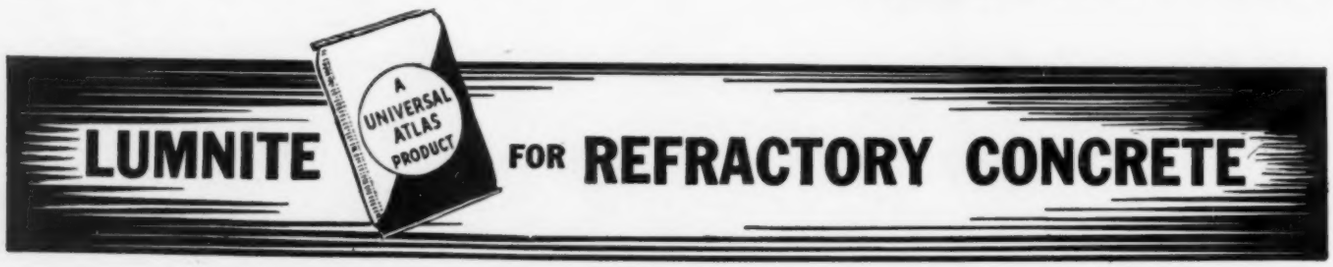
HERE'S how open-hearth flues built with Refractory Concrete look after five years' service. Note those sharp angles and smooth curves. There are no ragged walls, no flattened arches—no debris on the floor.

A 50% saving in cost was realized by using Refractory Concrete for this job in 1943. The cost advantage was confirmed later when two other sets of open-hearth flues at the same steel mill were rebuilt with Refractory Concrete.

This complex system of curved walls and tapering arches was cast in place without trimming, cutting, fitting or patching. The Refractory Concrete was made with LUMNITE cement and old firebrick crushed to size suitable for aggregate.

With LUMNITE, you can make Refractory Concrete for a great number of furnace construction and maintenance jobs. You can salvage your old firebrick or obtain low-cost aggregates for a wide range of temperature and insulation requirements.

For booklet describing these open-hearth flues and a manual on Refractory Concrete, write Lumnite Division, Universal Atlas Cement Company (United States Steel Corporation Subsidiary), Chrysler Building, New York 17, New York.

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# Control the Air and you control the Furnace

## Twice as many tons of air pass through the furnace as tons of steel

This is why **air** is the controlling factor in furnace operation. The ISLEY system supplies and controls the air. The supply is positive. The volume supplied by the fan goes to the burners. No leaky reversing valves and dampers interfere with the accuracy of controls.

The ISLEY draft control is mechanical, positive and independent of the temperature of regenerators, stacks and weather. There are no leaks to dilute the waste gas and cool it.

For more uniform furnace pressure, perfect control of combustion air, better heat recovery from waste gas, let us give you the complete ISLEY story.

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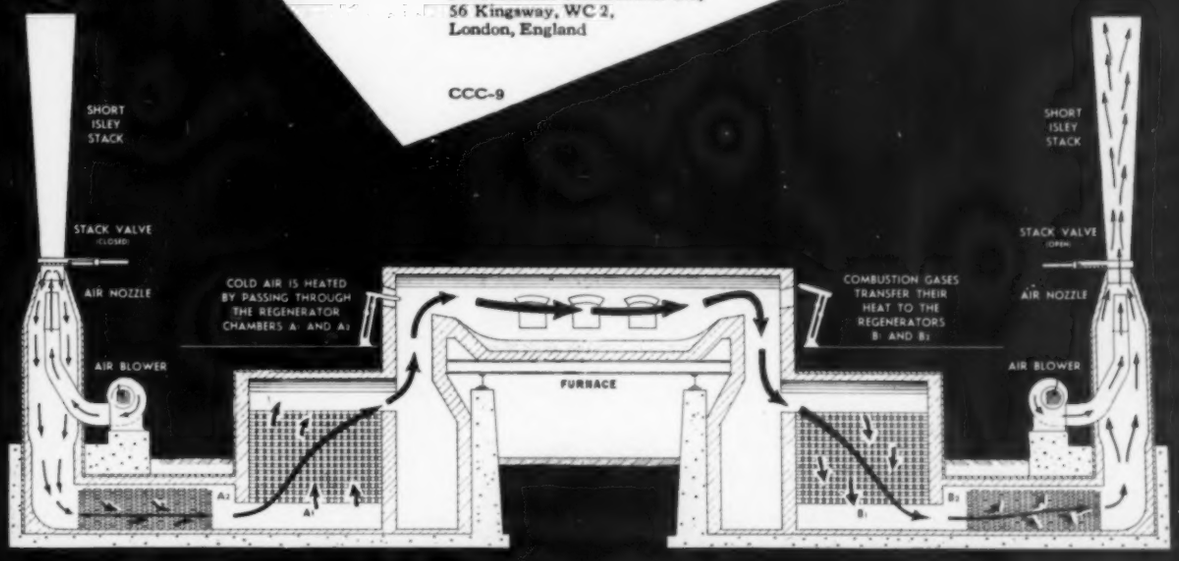
SHORT ISLEY STACK
STACK VALVE (CLOSED)
AIR NOZZLE
AIR BLOWER
COLD AIR IS HEATED BY PASSING THROUGH THE REGENERATOR CHAMBERS A1 AND A2
FURNACE
COMBUSTION GASES TRANSFER THEIR HEAT TO THE REGENERATORS B1 AND B2
SHORT ISLEY STACK
STACK VALVE (OPEN)
AIR NOZZLE
AIR BLOWER

# ISLEY FURNACE CONTROL SYSTEM

MOULDS **VALLEY** STOOLS

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INGOT POURING LADLE

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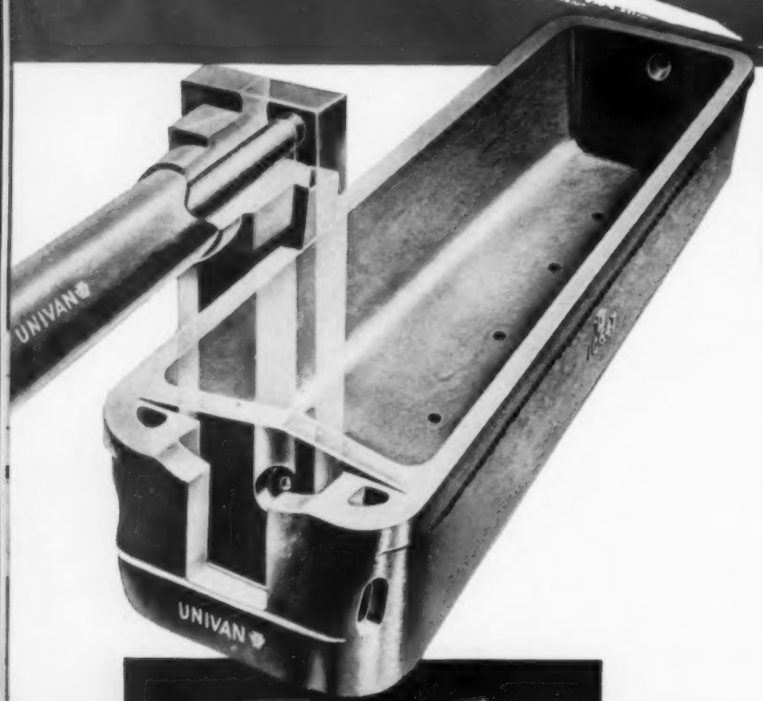
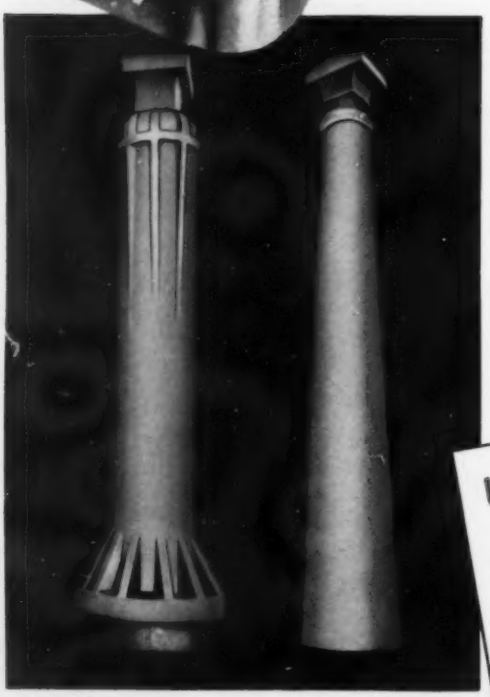
# PLANNING TO USE OXYGEN?




## Then You'll Want These Advantages Found Only in—

# UNION

## *DOUBLE-LIFE HEAD* CHARGING BOXES



Higher temperatures mean more frequent chargings—both of which put greater stresses and strains on your charging boxes. To head off the cost of losses and replacements change over to the charging boxes that can stand up under this more severe service—UNIVAN. Here's why: All corners are round because square corners do not lend themselves to the casting process . . . Open type head is replaced by our *Double-Life Head* adding strength and rigidity where most needed . . . Middle section of head is further reinforced with 3 ribs adjacent to hook slot . . . Boxes are cast from UNIVAN—that tough nickel-vanadium steel that maintains its strength under wide variations of heat and cold . . . Your request for further details and prices will receive immediate attention.

### UNION *Alloy Steel* PEELS

Except for the charge itself, no piece of unprotected metal is subjected to greater heat for a longer time than the peel. And, hot or cold, it must withstand severe shock and stresses as well. "Union" has developed for this tough service peels of heat and shock resistant alloys in designs that add months to their useful life . . . Glad to quote from your specifications on either rough or fully machined castings.

"UNIVAN" Tool Tough Steel

## UNION STEEL CASTINGS

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Cinder Pots • Slag Pots • Coupling Boxes • Spindles • Gears • Bells and Hoppers • Ingot Cars • Charging Cars • Annealing Boxes and Bases

UNION HAS COMPLETE MACHINE SHOP FACILITIES . . . ENABLING THE DELIVERY OF ITS PRODUCTS READY FOR USE

# The Modern Open Hearth

*. . . . this collection of data represents another installment in the "modern" series offered by the IRON AND STEEL ENGINEER . . . . acknowledgment is due the various open hearth operators and engineers who assisted in assembling and reviewing the material . . . .*

By T. J. Ess

▲ ALTHOUGH the writings of early historians indicate that iron was known some 3000-4000 years ago, research has shown that it was only since 500 B.C. that iron has been used more or less regularly. The crude furnaces and forges used to produce iron were the standard equipment of the steel industry for many years.

Steelmaking seems to have come into the industry during the 17th century with the development of the cementation and crucible processes, wherein carbon was induced into wrought iron by heating the iron in the presence of charcoal. A later development entailed melting the "steel" thus made in closed crucibles to equalize the carbon content.

Perhaps the real birth of steelmaking as we know it did not occur until the middle of the 19th century, when William Kelly, of Kentucky, and Henry Bessemer, of England, independently and almost concurrently worked out the original idea for what is now called the bessemer process. Subsequent improvements in this process were made by many individuals, among them Mushet, Thomas, Gilchrist, Holley and Jones.

Between 1860 and 1870 William Siemens carried on the experimental work which led to the open hearth furnace. Siemens' process, essentially pig-and-ore, began as an acid process, and was subsequently changed to basic. The pig-and-scrap process originated with the Martin brothers. In the United States, the first open hearth furnace was built in 1868 at the Trenton, New Jersey, plant of Messrs. Cooper, Hewitt and Company. The first plant to be built for the exclusive production of open hearth steel was the Otis Iron and Steel Company, at Cleveland, Ohio. In 1874 this company completed two 7-ton open hearth furnaces, and in 1878, added two 15-ton units.

The basic open hearth process fitted well into the raw material supply of the United States, and its capacity has steadily increased. In 1907 it caught up to the bessemer capacity, which has decreased rather steadily since 1906.

Approximately 88.5 per cent of the ingot steel produced in the United States now comes from the basic open hearth, with about 5 per cent from the acid bes-

**Figure 1 — Exterior view of modern open hearth shop, showing ramp leading to stockhouse (right) and to charging floor. Oil storage tanks are located beside the ramp.**

**TABLE I**

**Steel Capacity and Production for Various Years**

| | Total Steel-making capacity | Annual Production | | |
|---|---|---|---|---|
| | | Open hearth | Bessemer | Total‡ |
| 1875 | ..... | 8,000 | 335,000 | 403,000 |
| 1898 | 15,869,560 | 2,497,927 | 7,402,099 | 10,004,800 |
| 1901 | 24,039,064 | 5,215,066 | 9,758,898 | 15,090,426 |
| 1904 | 28,213,147 | 6,617,146 | 8,802,237 | 15,523,074 |
| 1906 | ..... | 12,298,063 | 13,748,930* | 26,205,913 |
| 1908 | 38,237,343 | 8,777,136 | 6,850,766 | 15,706,037 |
| 1912 | ..... | 23,274,410 | 11,567,249 | 35,001,459 |
| 1914 | 44,451,977 | 19,235,646 | 6,967,348 | 26,334,594 |
| 1917 | 55,571,555 | 38,246,760 | 11,737,555 | 50,467,880 |
| 1920 | 62,313,591 | 36,592,522 | 9,949,057 | 47,188,886 |
| 1921 | 64,262,027 | 17,460,578 | 4,497,851 | 22,157,853 |
| 1925 | 68,473,222 | 42,598,627 | 7,530,837 | 50,840,747 |
| 1929 | 71,438,516 | 54,155,235 | 7,977,210 | 63,205,490 |
| 1930 | 72,985,406 | 39,255,073 | 5,639,714 | 45,583,421 |
| 1932 | 78,780,913 | 13,336,210 | 1,715,925 | 15,322,901 |
| 1935 | 78,451,930 | 34,401,280 | 3,175,235 | 38,183,705 |
| 1940 | 81,619,496 | 61,573,083 | 3,708,573 | 66,982,686 |
| 1941 | 85,158,150 | 74,380,619 | 5,578,071 | 82,839,259 |
| 1942 | 88,886,550 | 76,501,957 | 5,553,424 | 86,031,931 |
| 1943 | 90,589,190 | 78,621,804 | 5,625,492 | 88,836,512 |
| 1944 | 93,854,420 | 80,363,958* | 5,039,923 | 89,641,600* |
| 1945 | 95,505,280 | 71,939,602 | 4,305,318 | 79,701,648 |
| 1946 | 91,890,560 | 60,711,963 | 3,327,737 | 66,602,724 |
| 1947 | 94,233,640 | 76,812,570 | 4,232,543 | 84,783,981 |

*Record yearly production.
‡Includes open hearth, bessemer, electric and crucible.

semer, 5 per cent from the electric furnace, and 1.5 per cent from the acid open hearth.

At the beginning of 1948, the steel-making capacity of the United States was as follows:

| | Net tons per year |
|---|---|
| Basic open hearth capacity | 82,110,690 |
| Acid open hearth capacity (estimated) | 1,500,000 |
| Total open hearth capacity | 83,610,690 |
| Bessemer capacity | 5,226,000 |
| Electric furnace and crucible capacity | 5,396,770 |
| Grand total | 94,233,460 |

## STEEL

Steel is not exactly a specific product. It is defined as a refined ferrous product between cast iron and wrought iron. It is variously classified according to process of manufacture, composition or use.

According to composition, there are two broad types of steel, carbon and alloy. The American Iron and Steel Institute has defined these types as follows:

"Steel is classed as carbon steel when no minimum content is specified or required for aluminum, boron, chromium, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium or zirconium, or any element added to obtain a desired alloying effect; when the specified minimum content for copper does not exceed .40 per cent; or when the maximum content specified for any of the following elements does not exceed the percentages noted: manganese 1.65 per cent; silicon .60 per cent; copper .60 per cent.

"Steel is classed as alloy steel when the maximum of the range given for the content of alloying elements exceeds one or more of the following limits: manganese 1.65 per cent; silicon .60 per cent; copper .60 per cent; or in which a definite range or a definite minimum quantity of any of the following elements is specified or required within the limits of the recognized commercial field of alloy steels; aluminum, boron, chromium up to 3.99 per cent, cobalt, columbium, molybdenum, nickel, titanium, tungsten, vanadium, zirconium, or any other alloying element added to obtain a desired alloying effect."

Alloy steel forms 25-30 per cent of the total production.

In order to simplify steel specifications, the American Iron and Steel Institute has set up chemical compositions and physical test properties for a wide range of standard steels. A system of symbols is used to identify the various classifications. In this system, capital letter prefixes are used to indicate types of steel by process of manufacture. Numbers are used to indicate grades of steel by chemical composition or tensile properties. Lower case letters may be used as suffixes to indicate various special requirements affecting quality. The prefix letter B denotes acid bessemer carbon steel, C denotes basic open hearth carbon steel, and D denotes acid open hearth carbon steel. CB denotes either acid bessemer or basic open hearth carbon steel at the option of the manufacturer. For alloy steels, no prefix is used except the letter E to denote electric furnace steel.

A four-numeral series designates carbon and alloy steels specified to chemical composition ranges. The series is essentially like the system used originally by the Society of Automotive Engineers, but is extended to include other grades of steel. Five numerals are used for grades having a mean carbon of 1.00 per cent or higher, and for certain types of alloys. The last two digits of the four-numeral series are intended, so far as feasible, to indicate the approximate middle of the carbon range; for example, 20 represents a range of .18-.23 per cent. It is sometimes necessary to deviate from this rule and to interpolate numbers in the case of some carbon ranges, and for variations in manganese, phosphorus or sulphur with the same carbon ranges.

The basic numbers for the various grades of steel are as follows:

| Series designation | Types and classes |
|---|---|
| 10XX | — Basic open hearth and acid bessemer carbon steel grades, non-sulphurized and non-phosphorized. |
| 11XX | — Basic open hearth and acid bessemer carbon steel grades, sulphurized but not phosphorized. |
| 12XX | — Basic open hearth carbon steel grades, phosphorized. |
| 13XX | — Manganese 1.75 per cent. |
| 23XX | — Nickel 3.50 per cent. |
| 25XX | — Nickel 5.00 per cent. |
| 31XX | — Nickel 1.25 per cent, chromium .65 or .80 per cent. |
| 33XX | — Nickel 3.50 per cent, chromium 1.55 per cent. |
| 40XX | — Molybdenum .25 per cent. |
| 41XX | — Chromium .95 per cent, molybdenum .20 per cent. |
| 43XX | — Nickel 1.80 per cent, chromium .50-.80 per |

cent, molybdenum .25 per cent.

46XX — Nickel 1.80 per cent, molybdenum .25 per cent.

48XX — Nickel 3.50 per cent, molybdenum, .25 per cent.

50XX — Chromium .65 per cent.

51XX — Chromium .80, .95, or 1.05 per cent.

5XXXX — Carbon 1.00 per cent, chromium .50, 1.00 or 1.45 per cent.

61XX — Chromium .80 or .95 per cent, vanadium .10 or .15 per cent minimum.

86XX — Nickel .55 per cent, chromium .50 per cent, molybdenum .20 per cent.

87XX — Nickel .55 per cent, chromium .50 per cent, molybdenum .25 per cent.

92XX — Manganese .85 per cent, silicon 2.00 per cent.

93XX — Nickel 3.25 per cent, chromium 1.20 per cent, molybdenum .12 per cent.

94XX — Manganese 1.00 per cent, nickel .45 per cent, chromium .40 per cent, molybdenum .12 per cent.

97XX — Nickel .55 per cent, chromium .17 per cent, molybdenum .20 per cent.

98XX — Nickel 1.00 per cent, chromium .80 per cent, molybdenum .25 per cent.

The 10XX, 11XX and 12XX series are carbon steels, while the others are alloys. In carbon steels, standard analysis ranges show carbon .05 to 1.05 per cent, manganese .25-1.65 per cent, silicon .05-.30 per cent, maximum phosphorus .04-.045 per cent (up to .11 for phosphorized steels), and maximum sulphur .05-.06 per cent (up to .32 for sulphurized steels). For standard alloy steels, carbon ranges .06-1.10 per cent, manganese .25-2.10 per cent, silicon .20-2.20 per cent, maximum phosphorus .025-.05 per cent, and maximum sulphur .025-.06 per cent.

Detailed lists of these steels, with their ranges of analysis, permissible variations, etc., are given in the AISI Steel Products Manuals, as well as various other references. Of course, many other analyses, termed non-standard, are produced by the steel industry to meet special requirements of customers.

In practice, steel with less than .10 per cent carbon is called "dead-soft" steel, or perhaps ingot iron. Steels containing .10-.30 per cent carbon are "low carbon," those with .30-.85 per cent carbon are "medium carbon," and those of .85-1.50 per cent carbon are "high carbon" steels.

**TABLE II**

**Tabulation of Open Hearth Furnace Sizes**

| Rated capacity per heat, net tons | Number of open hearth furnaces in the United States | | |
|---|---|---|---|
| | July 1, 1938 | December 31, 1942 | April 1, 1948 |
| Up to 24 | 20 | 16 | 10 |
| 25- 39 | 28 | 29 | 17 |
| 40- 54 | 71 | 52 | 44 |
| 55- 69 | 89 | 63 | 45 |
| 70- 84 | 103 | 96 | 61 |
| 85- 99 | 49 | 46 | 65 |
| 100-114 | 221 | 194 | 173 |
| 115-129 | 96 | 103 | 133 |
| 130-144 | 128 | 152 | 115 |
| 145-159 | 41 | 27 | 59 |
| 160-174 | 99 | 115 | 72 |
| 175-189 | 8 | 17 | 50 |
| 190-204 | 9 | 40 | 73 |
| 205-219 | 0 | 0 | 0 |
| 220-234 | 12 | 12 | 37 |
| 235 and over | 21 | 6 | 7 |
| Total | 995 | 968 | 961 |
| Average furnace size | 111.7 | 115.6 | 126.8 |

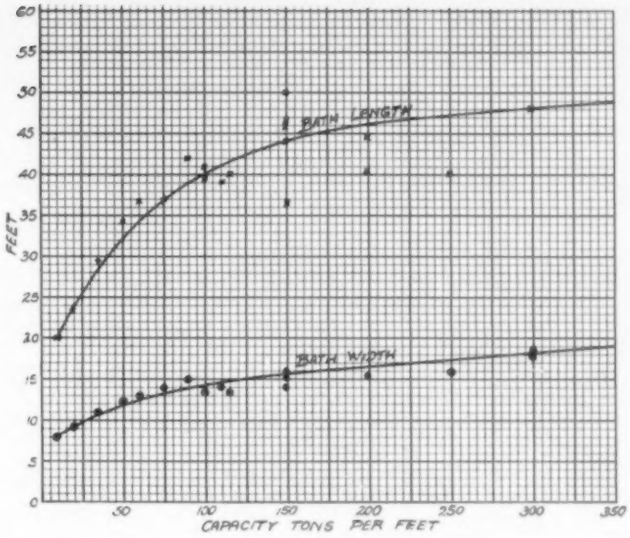



**Figure 2 — Bath dimensions in the open hearth furnace fall along the curves shown above.**

## THE FURNACE

Open hearth furnaces may be found ranging from 5-400 tons capacity. At present there are 944 open hearth furnaces in the steel industry of the United States. These furnaces fall into size groups approximately as given in Table II. Although almost one-half of the furnaces fall between 100 and 150 tons, the most recent installations have gone to larger units, with several companies practically standardizing on furnaces of 200 or 225 tons capacity.

A complete list of open hearth installations in the United States is given in the appendix of this article.

While generally similar in design, the proportions vary considerably with the furnace size. Length of hearth ranges from 20 ft up to 50 or 52 ft, while width ranges between 8 ft and 18½ ft.

Hearth area may range 8-10 sq ft per ton for small furnaces, through 4-5 for medium furnaces, and down to 2.5-3.0 for very large furnaces. In calculating the holding capacity of a hearth, a weight of 430 lb per sq ft is a good average for molten steel. It should also be remembered that the slag may add as much as 6 in. depth to that of the bath, and that the volume of the bath may increase during the lime boil by as much as 50 per cent with a high scrap charge, and by 100 per cent or more with a high ore charge. A widely accepted method of design is to calculate the nominal metal holding capa-

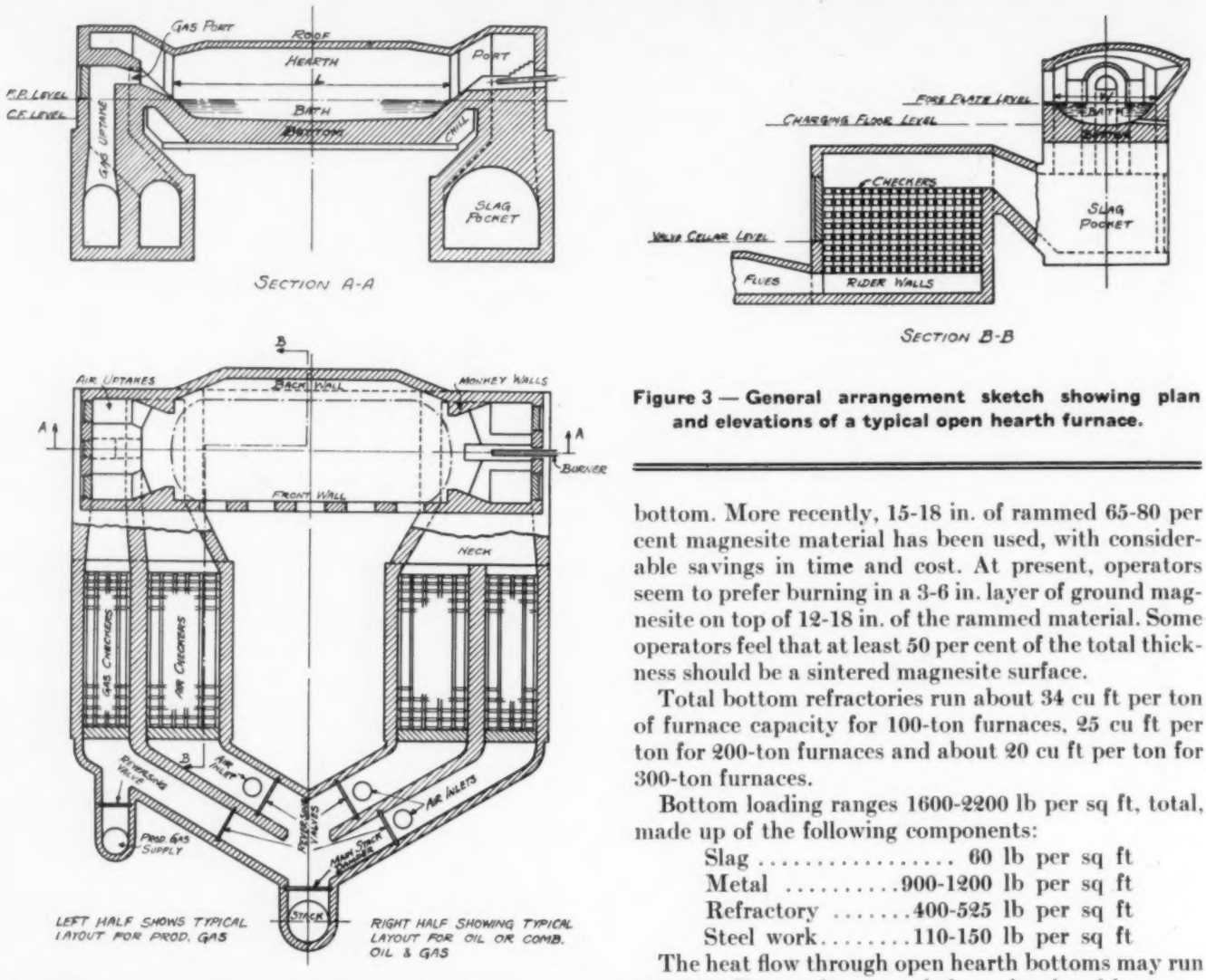



**Figure 3 — General arrangement sketch showing plan and elevations of a typical open hearth furnace.**

city below a plane 6 in. below the foreplate. Actually, by building up the banks, a furnace may be over-charged 15-25 per cent, giving a deeper bath.

Bath depths vary widely, with maximum depths of 48 in. in some of the largest furnaces, but shallower baths are preferred. A majority of furnaces operate with baths of 28-32 in. depth, with some up to 39 in. Some operators favor a depth of 26-28 in. for furnaces of 150-200 tons capacity, and feel that a deeper bath cuts production.

Maximum depth of hearth, from foreplate to bottom refractory, usually ranges 30-48 in., while the distance between foreplate and bottom plate runs 66-88 in.

*Bottoms*—Hearth support commonly consists of 24 in. I-beams, longitudinally, on 16 in.-24 in. centers, topped by 15 in. I-beams, cross-wise, on 18 in.-24 in. centers. The steel plate pan bottom is usually of ¾ in. or 1 in. plate.

Bottom refractories usually run 30 in.-48 in. thick at the center of the hearth, consisting from the bottom up of 2-4 in. of insulation, 4½-13½ in. of fire clay brick, 9-15 in. of burned chrome or magnesite brick, and 15-24 in. of magnesite. In the past, ground magnesite (sometimes mixed with open hearth slag) was burned into the bottom. More recently, 15-18 in. of rammed 65-80 per cent magnesite material has been used, with considerable savings in time and cost. At present, operators seem to prefer burning in a 3-6 in. layer of ground magnesite on top of 12-18 in. of the rammed material. Some operators feel that at least 50 per cent of the total thickness should be a sintered magnesite surface.

Total bottom refractories run about 34 cu ft per ton of furnace capacity for 100-ton furnaces, 25 cu ft per ton for 200-ton furnaces and about 20 cu ft per ton for 300-ton furnaces.

Bottom loading ranges 1600-2200 lb per sq ft, total, made up of the following components:

| | |
|---|---|
| Slag | 60 lb per sq ft |
| Metal | 900-1200 lb per sq ft |
| Refractory | 400-525 lb per sq ft |
| Steel work | 110-150 lb per sq ft |

The heat flow through open hearth bottoms may run 800-1200 Btu per hr per sq ft for uninsulated bottoms, and down to 500-550 for insulated bottoms. Inasmuch as the heat thus lost must be first driven through the slag and metal bath, it is particularly desirable to keep this loss at a minimum.

Contour of the furnace bottom should be maintained so that all metal and slag flows out of the tap hole. Hollows should be filled by rabbling or blowing out molten material and shoveling in magnesite or dolomite mixes. The tap hole, which is about 6 in. in diameter, should have a continuous fall (about 1 in. per ft) from the lowest point of the bottom. It is first formed by placing a steel pipe through a hole in the brickwork and tamping chrome ore or a mixture of magnesite and a binder around the pipe, and facing it off with dolomite. It should not be allowed to build up or become crooked or constricted while in use.

*Walls*—Front walls are usually made 18 in. thick at the foreplate line, corbeled back to 13½ in. thick, and out again at the top to 18 in. In some cases they are made 18 in. thick from top to bottom, and contain pipes for water-cooling. Their height above the foreplate varies with furnace size, ranging from 4 ft 6 in. to 5 ft 6 in., although some authorities recommend that front walls be made higher, ranging from 5 ft 6 in. for 100-ton furnaces up to 6 ft or more for 300-ton furnaces. Five

charging doors are placed in the front wall of practically all modern furnaces. These door openings have removable water-cooled door frames, closed by water-cooled, refractory-lined doors.

Back walls in modern furnaces are commonly of the sloping type, 18 in. or more in thickness. They may be the same height as the front walls, but with sloping backs. The height is often less, running 3-4½ ft. Forming angles of 40-50 degrees with the horizontal, sloping backs are variously made of silica brick, fire brick, chrome brick, or magnesite brick, covered over with 4-10 in. of granular bottom material. A typical back wall may consist of 9 in. of hard-burned firebrick, covered by 4½ in. of chrome brick, and then 5 in. of granular material.

Plate or cast sections are usually used on the outside of sloping backwalls. Insulation which will withstand high temperatures may be used on back walls, and reduces heat loss about one-half.

*Roof*—Thickness of the roof runs 12-18 in., with operators leaning toward the greater thickness, although some feel that thicknesses over 13 in. necessitate lower fuel input, thus holding down furnace production. Roofs are commonly of arched design, with the brick laid in ring arch, bonded arch or ribbed arch construction. Strength is added by the use of ribs 6-9 in. wide, projecting 2½-4½ in. above the top of the roof, and running across the furnace on 24-36 in. centers. In many cases, certain sections of the roof are made thicker than the remainder, so as to give greater wear where erosion is greatest. Panels, 3 in. thicker than the main roof, may be placed along the back skewback and sometimes along the front skewback. These panels may be 2 or 3 ft wide, and may extend from one knuckle to the other. For furnaces with sloping back walls, good roof design may be as shown in Table III.

Roof profile, from end to end of the furnace, varies with the type of fuel used and with the ideas of the operators. Adjacent to the ends of the furnace, most furnace roofs have a straight section ranging 2-8 ft in length. Next come sloped sections leading down to the knuckles. In some furnaces, this sloping section starts at the end walls. Furnaces fired only with gaseous fuels have sharp roof slopes—almost 30 degrees, and as high as 45 degrees—with the angle of fuel injection about one-half of the roof angle. With liquid fuels, roof slopes are milder, flame direction being attained by direction of the driven fuel jet. Between the knuckles, the roof profile may be straight and horizontal, or it may rise somewhat from each knuckle before becoming horizontal. The former profile is more common with the milder slopes of furnaces fired with liquid fuel, while the latter often accompanies the sharp slopes of the gas-fired furnaces.

Recently, in connection with basic refractories, some installations of suspended radial arches with spring-loaded skews have been made.

At each side of the furnace, the roof is carried by heavy skewback channels, 16-20 in. high, located at the top of the front and back walls. These skewback channels are supported by the furnace buckstays.

*Buckstays* are generally of slabs or laminations of plate, although some cast steel sections are still used. Two such slabs, approximately 5 in. x 15 in. in section, are paired 18-24 in. apart. These pairs are spaced on 8-9 ft centers. The buckstays are pinned at the bottom to the cross beams supporting the furnace pan or rigidly connected to the pan and cross beams, and are tied across the top of the furnace by a binding of structural members, or, on older furnaces, by tie rods. In some cases, to obtain greater rigidity, the back buckstays extend down to piers on the floor of the pouring pit.

At the furnace ends, regular I-beams and channels or smaller slabs, are used for furnace binding, being supported on the slag pocket brickwork or steelwork.

## FURNACE PROPORTIONS

The volume of the furnace laboratory, above the foreplate and between the knuckles, averages about 30

**TABLE III**

**Roof Arch Proportions**

| Width of bath, ft | Height of front wall, ft-in. | Span and radius of arch, ft-in. | a ft | b ft | $H_1$ ft | $H_2$ ft |
|---|---|---|---|---|---|---|
| 12 | 5-6 | 17-9 | 7.5 | 10.3 | 1.70 | 3.17 |
| 14 | 5-8 | 19-9 | 8.3 | 11.4 | 1.91 | 3.53 |
| 16 | 5-10 | 21-9 | 9.2 | 12.6 | 2.08 | 3.89 |
| 18 | 6-0 | 23-9 | 10.1 | 13.7 | 2.28 | 4.24 |
| 19 | 6-1 | 24-9 | 10.5 | 14.3 | 2.36 | 4.43 |
| 20 | 6-1¾ | 25-9 | 10.9 | 14.9 | 2.46 | 4.61 |

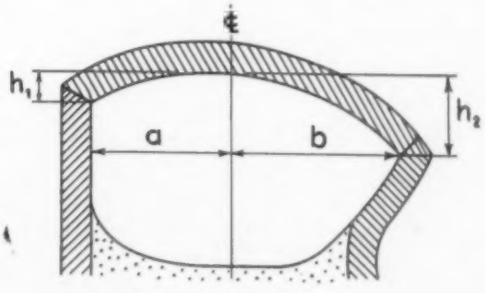
a = ft from centerline of hearth horizontally to roof contact on front wall.

b = ft from centerline of hearth horizontally to roof contact on back wall.

$H_1$ = ft from highest point inside of roof vertically down to roof contact on front wall.

$H_2$ = ft from highest point inside of roof vertically down to roof contact on back wall.

Included angle in all cases = 60 degrees.



cu ft per ton of rated furnace capacity. Vertical sectional area at the center of the furnace above the foreplate ranges 95-200 sq ft, or .5-.75 sq ft per ton of furnace capacity. Modern units show .55-.65 sq ft per ton of furnace capacity. Gas velocities through the furnace usually run 10-18 fps, varying with the length of the furnace. Actually, the entire sectional area above the bath is probably not filled by the traveling gases, so this velocity is perhaps only an indication.

Throat area at the knuckle and monkey walls is at best a compromise between entrance and exit service. This area ranges 45-150 sq ft, or .25-.70 sq ft per ton. Throat area has been recommended so as to give exit gas velocities of 13-18 fps, although values far different from this may be found in practice, with apparently satisfactory results. A survey of existing furnaces shows throat areas of .2-.25 sq ft per ton for furnaces burning natural gas, .35 per ton for producer gas furnaces, and .3 -.65 sq ft per ton for oil-fired furnaces. Some oil-burning furnaces recently constructed show throat areas of .4-.5 sq ft per ton of furnace capacity. The present tendency is toward opening up the furnace ends as much as may be practical.

The aprons of the furnace ends are usually 12-15 in. above the foreplate line, and slope up at an angle of about 20 degrees. The length of the furnace ends may range 12-18 ft, with increased length seeming to give better fuel practice and production. This length varies with the length of the bath, and should range 30-35 per cent of the bath length. Distance from the bath line to the fuel port nose runs, correspondingly, 7.5-12.5 ft, or 20-25 per cent of the bath length. Insofar as possible, furnace ends, from the throat out, should be designed to give a constantly increasing area.

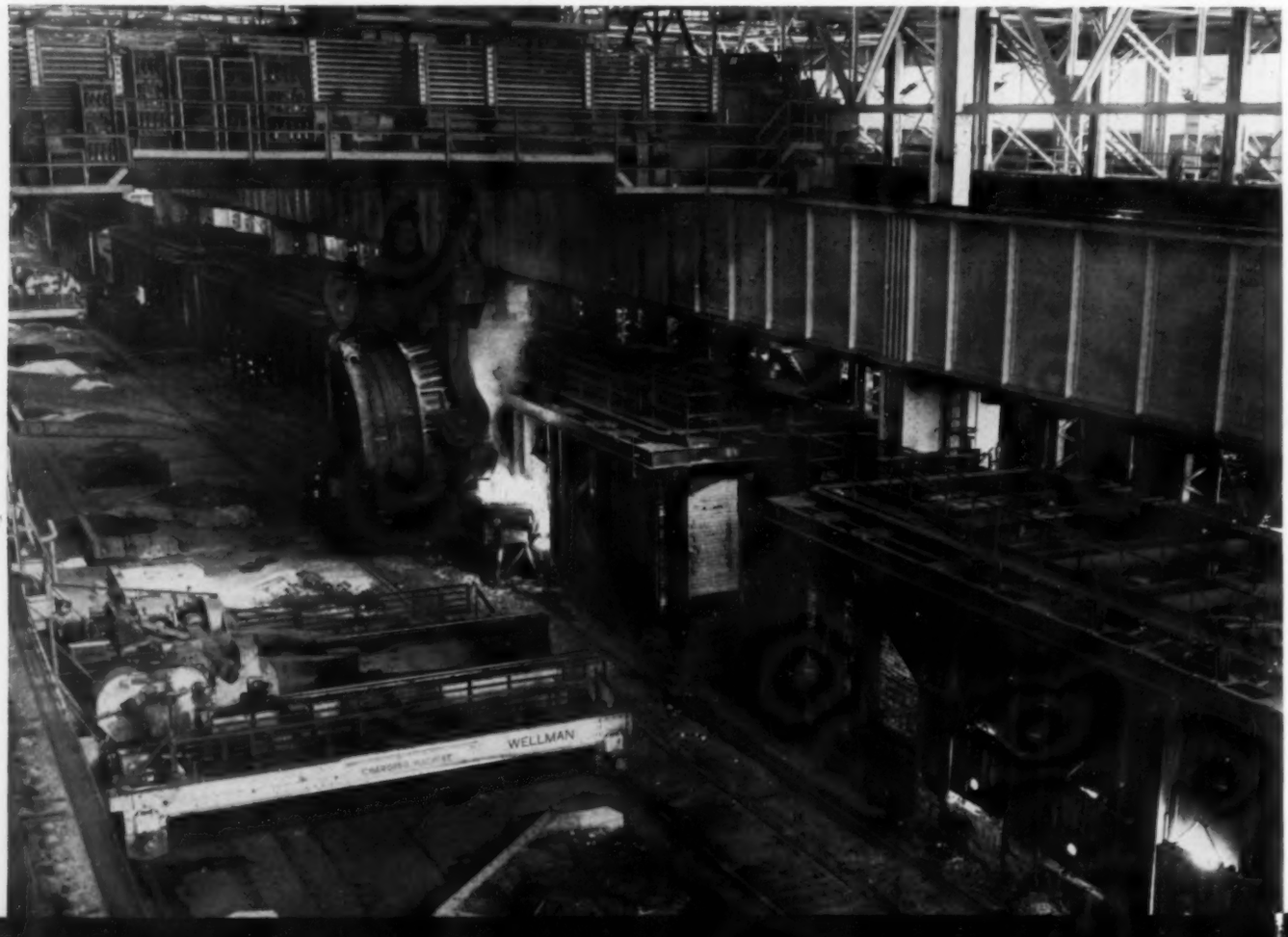
Gas ports in producer gas-fired furnaces show .025-.030 sq ft per ton of furnace capacity, which will give gas velocities of 120-180 fps. Gas uptakes range 9-15 sq in. per ton of furnace capacity. Gas valve areas show 14-28 sq in. per ton. Gas producer grate areas average 3-6 sq ft of producer grate area per ton, while producer gas mains average about 18 sq in. cross sectional area per sq ft of producer grate area.

Air uptakes on each end of the furnace may range .12-.50 sq ft per ton of furnace capacity, tending toward the larger side. Several recent installations show .4 sq ft per ton of capacity. Incoming air velocity should not exceed 10 or 12 fps in the air uptakes.

The total downtake area on each end of the furnace, which is the same as air uptake area when the fuel is not regenerated, may range 25-96 sq ft, or .17-.50 sq ft per ton of furnace capacity, with the more generous area preferred. Downtake areas have been recommended so as to give exit gas velocities not exceeding 18 fps, although under maximum firing rates, this often exceeds 20 fps in existing furnaces. Modern practice shows downtake areas on each end of the furnace of about .4-.45 sq ft per ton of furnace capacity. The downtake area should exceed the throat area of the furnace if the furnace is to be fast working. If downtake area is less than throat area, maintenance of furnace ends will be high.

Some furnace designs, such as the Rose, McKune,

**Figure 4 — This view of a charging floor affords a good view of the furnace steelwork. Hot metal is being added to the furnace in the center. In this shop, low retaining walls are built on the floor to form bins for dolomite, etc.**



etc., use sliding dampers or ports which can be moved to open up the outgoing end of the furnace, and then moved back to provide velocity and direction to the incoming air and gas.

*Slag pockets*—Directly beneath the furnace ends are the slag pockets, where a considerable amount of slag accumulates during the furnace campaign. This accumulation may range 4-16 lb per ton of ingots produced, divided, of course, between the two furnace ends. Deposits are greater with liquid fuels than with gaseous fuel. The deposit may analyze 53-65 per cent iron oxide, 27-37 per cent silica, 3-6 per cent lime and magnesia, and small amounts of manganese oxide and alumina. This material weighs about 150 lb per cu ft. In furnaces with basic end construction, this deposit is very low in silica—in fact it can be used in the furnaces as sinter.

Slag pockets range 10-25 ft in length, 8-16 ft (combined) in width, and 8-14 ft in height. Their volume on each end of the furnace ranges from 13 to 25 or more cu ft per ton of furnace capacity. Several modern installations use a volume factor of 25 cu ft per ton. Vertical area (width x height) of the pockets on one end of the furnace should be such that the pocket will accommodate the slag accumulated between rebuilds and yet permit exit gas velocities of 15 fps or less. Where pockets are small or slag deposits excessive, means of draining the pit into an auxiliary pit may be provided.

On furnaces fired with producer gas, the slag pocket must be divided between gas and air in proportions ranging 35-65 to 45-55 per cent. With other fuels, a single, common slag pocket on each end of the furnace is preferred.

Slag pockets usually are constructed with side walls of 18 in. of silica brick, backed up with 9-13½ in. of common brick or 2½-4½ in. of insulation. Where center walls are used to divide the slag pockets, they are usually 2½-3 ft thick, of silica brick. Steel plates may be used to cover slag pocket walls, except over the cleanout bulkheads on the pit side of the furnace. Slag pocket bulkheads are of silica brick, usually 13½ or 18 in. thick, and sometimes insulated. Sometimes two thinner walls are used with an air space between.

In many cases, the bottoms of the slag pockets are built so as to incorporate some mechanical means of loosening and breaking up the slag deposit, so as to gain time when the pockets are cleaned out for furnace rebuilding. This is not necessary in furnaces with basic end construction, as the deposit in such cases is loose and granular, and can be removed easily by shovel or mechanical scoop.

*Fantails*—Fantails connect the slag pockets to the regenerator. They are constructed with silica brick sidewalls 13½-18 in. thick, usually backed by common brick or insulating material, and silica brick roofs 12-18 in. thick, sometimes insulated. Fantail bottoms may be 9-18 in. of silica brick, backed by common brick or insulation, or they may consist of up to 24 in. of fire clay brick.

Fantails usually range 7-12 ft in length, with sectional areas of 55-215 sq ft, or .3-.5 sq ft per ton of furnace capacity. The angle made by the fantail should be as small as possible, or, in other words, the centerline of the slag pockets should be as close to the centerline of the regenerators as possible. Gas velocities of 12-25 fps are found in fantails of modern furnaces.

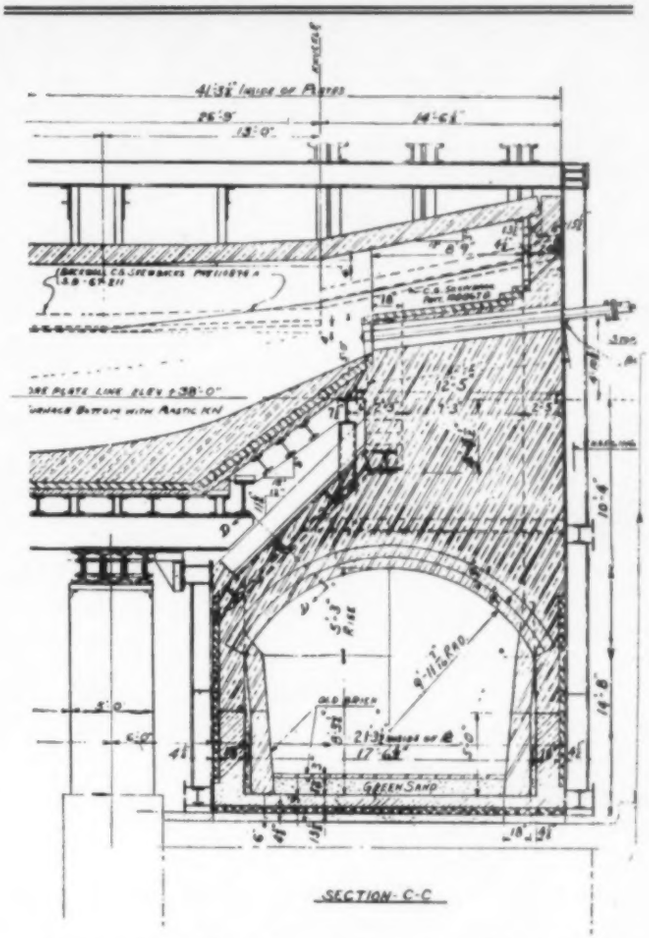



**Figure 5 — This sketch shows some details of the port end of an oil-fired furnace that has shown an excellent operating record.**

*Regenerators* — Regenerator chambers generally range 21-31 ft in length, 17-27 ft (combined) in width, and 16-25 ft in height. The width is usually divided into two separate chambers. When producer gas is used as fuel, the air chamber comprises 57-67 per cent of the total width. With liquid fuel, when both chambers are used for air, the two may be equal in width, the division being made to reduce the roof span of sprung arches; with suspended roofs, the division wall may be eliminated.

Regenerator side walls usually are constructed of 13½-18 in. of fire clay brick, backed by 9 in. of common brick or by 4½ in. of insulating brick and ¼ in. steel plate. Roofs are sprung arches (in some cases, suspended) of fire clay brick, 12-15 in. thick.

Checkerwork is built into the regenerator chambers in heights of 8-18 ft, leaving a free space of 4-6 ft above the checkerwork and 3-5 ft below the checkerwork. Checkerwork usually fills 60-75 per cent of the regenerator chamber volume. The volume of checkerwork in each end of the furnace ranges 45-100 cu ft per ton of furnace capacity. A rule-of-thumb states that each end of the furnace should have 3.3 cu ft of checkerwork per cu ft of air per sec per 100 F rise in air temperature. The air checker volume runs 1.3-2.0 times that of the gas checkers. On furnaces where fuel is not regenerated, the two chambers may be equal in width, the division

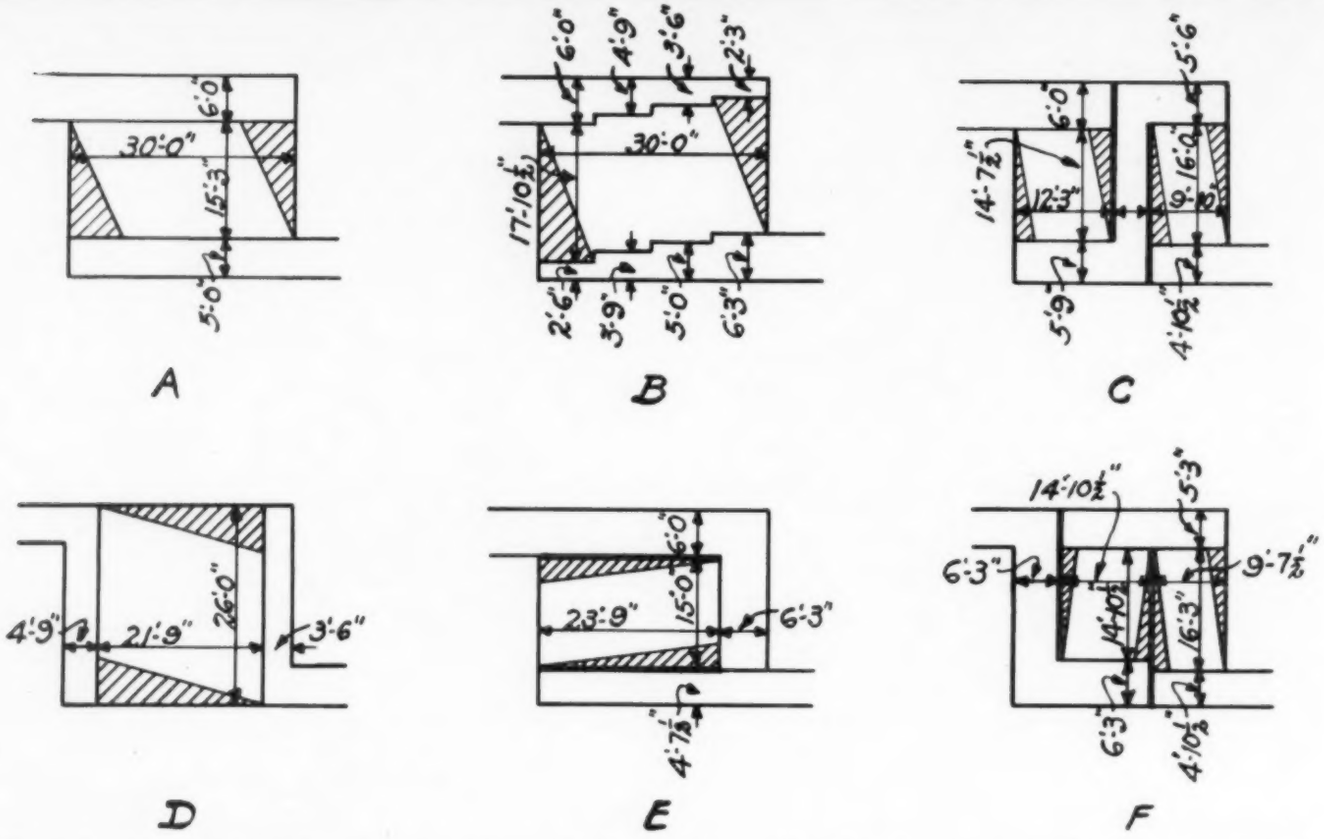
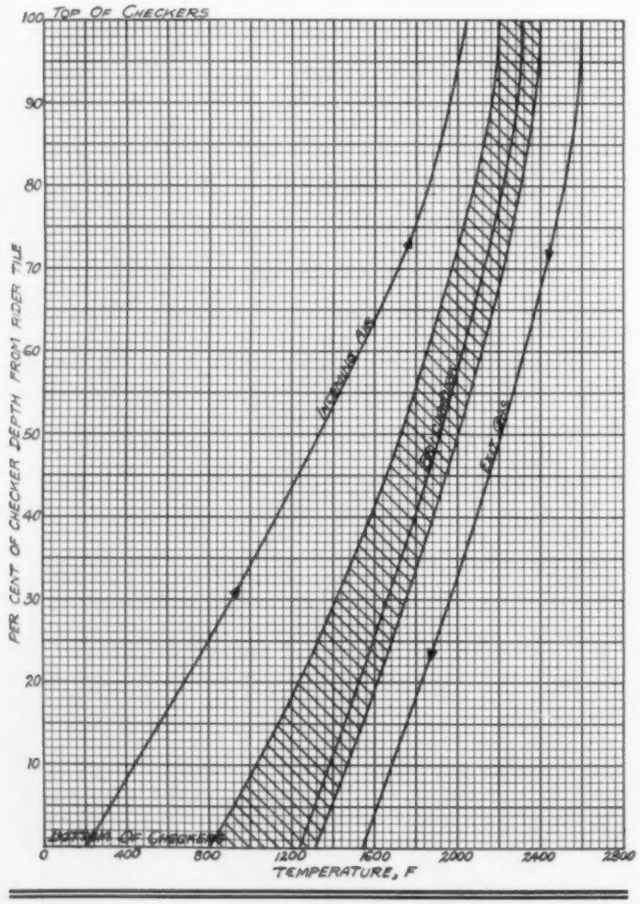



**Figure 6 — These sketches show various arrangements of regenerators with different courses of gas flow. The arrangements in A and B are generally used, although C is giving fine results in several plants.**

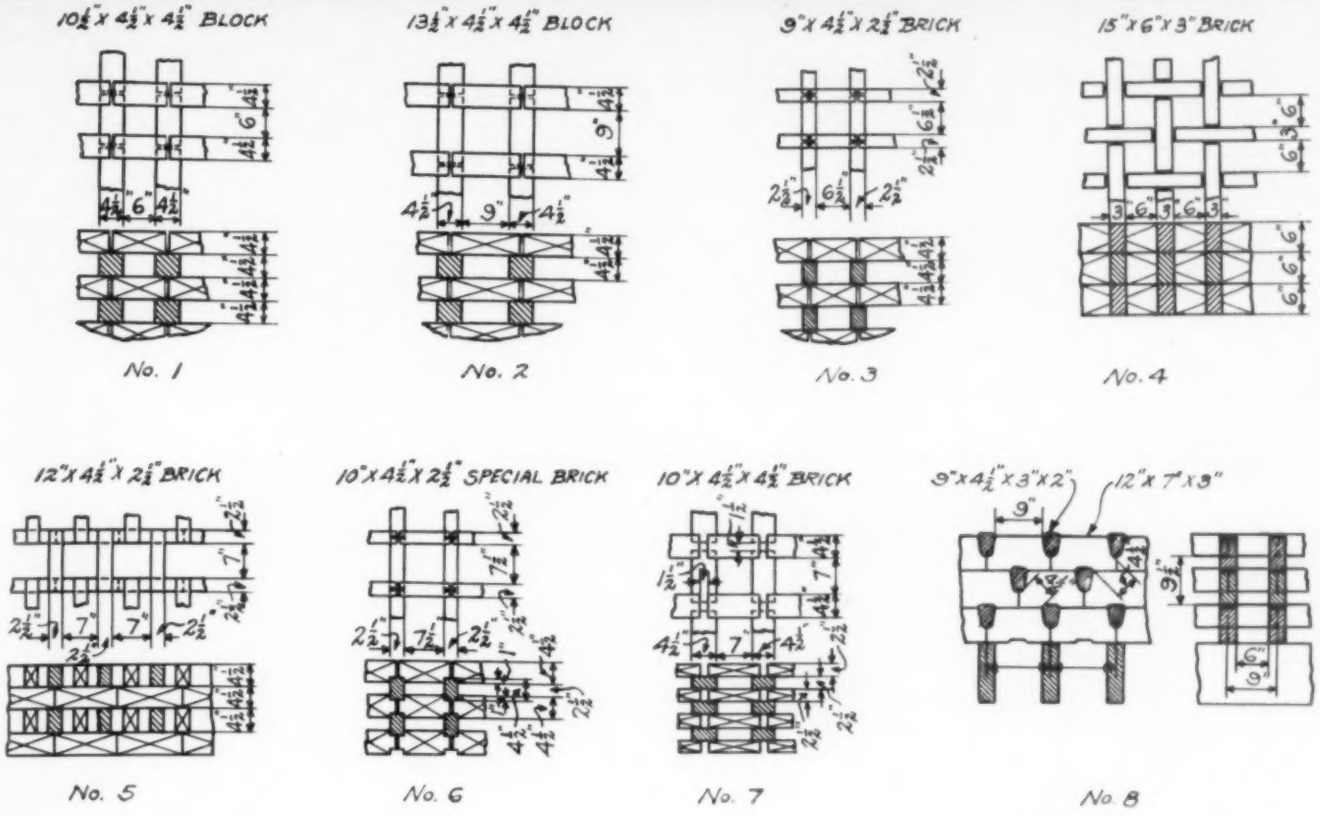



being made for structural reasons. Although a large volume of checkerwork is desirable, modern large furnaces seldom show more than a total of 50 cu ft of checkerwork on each end of the furnace per ton of furnace capacity, but with a trend toward greater depth in proportion to length.

Checkerwork is built in various designs. Figure 6 shows some arrangements of checkerwork offering different courses of gas flow. Most of the existing installations use the arrangements shown in A or B, although the multiple-pass arrangement offers much greater length of travel of the gases, and, properly designed and constructed, will result in better regeneration and better furnace economy. The arrangement shown in C is giving excellent results in several shops. The first passes contain about 58 per cent of the total checker volume, with approximately 42 per cent in the second passes. The path of flow through the checkerwork is about 31 ft, plus the idler flue between the two passes. All two-pass arrangements entail a draft loss that necessitates mechanical draft, both forced and induced.

There are also various types of checker construction, using brick 9-18 in. long, 4½-6 in. wide, and 2½-4½ in. thick, as well as a number of special patented shapes. Thicknesses of 2½-3 in. are preferred by many. Regular

**Figure 7 — Various tests indicate the temperature distribution in regenerators to be approximately as shown in these curves.**


10½" x 4½" x 4½" BLOCK
13½" x 4½" x 4½" BLOCK
9" x 4½" x 2½" BRICK
15" x 6" x 3" BRICK
No. 1
No. 2
No. 3
No. 4
12" x 4½" x 2½" BRICK
10" x 4½" x 2½" SPECIAL BRICK
10" x 4½" x 4½" BRICK
9" x 4½" x 3" x 2"
12" x 7" x 9"
No. 5
No. 6
No. 7
No. 8

| CHECKER No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| SIZE OF VERTICAL FLUE | 6"x6" | 9"x9" | 6¾x6¾" | 6"x6" | 7"x7" | 7¾x7¾" | 7"x7" | 6"x8" |
| No. OF PIECES PER CU. FT. OF CHECKER WORK | 3.48 | 2.1 | 4.74 | 3.56 | 3.81 | 4.94 | .523 | 238<br>224 |
| 9" EQUIVALENTS IN EACH PIECE | 2.10 | 2.7 | 1.00 | 2.67 | 1.33 | 1.05 | 1.11 | 2/4<br>604 |
| 9" EQUIVALENTS PER CU. FT. OF CHECKER WORK | 7.31 | 5.67 | 4.74 | 9.48 | 5.07 | 5.19 | 5.81 | 7.42 |
| Sq. FT. OF EXPOSED HEATING SURFACE PER CU. FT. OF CHECKER WORK | 3.59 | 2.95 | 3.74 | 3.56 | 3.57 | 4.03 | 5.25 | 3.86 |
| Sq. FT. OF FREE AREA PER Sq. FT. OF HORIZONTAL CHECKER WORK | .33 | .44 | .52 | .44 | .54 | .56 | .37 | .49 |

**Figure 8 — Checkerwork may be built in many designs, some of which are shown above. The choice of a design is usually a compromise between stability, cost, efficiency in heat exchange, and practicality in keeping them open.**

shapes are usually laid either in open flue arrangement or in basket weave or chimney arrangement, or perhaps alternate courses of each. Figure 8 gives a number of checker designs, with characteristic data for each.

It will be noted from this figure that vertical flues range from 6 × 6 in. to 9 × 9 in., and installations may be found with even larger flues. Checker flue size is somewhat of a compromise between the desirability of small flues for maximum effectiveness in heating, and their disadvantage from the standpoint of becoming clogged with dust from the furnace. Flues 7½ × 7½ in. have been widely used in recent furnaces.

Refractory volume in the various types of checkers amounts to 4.74-9.48 nine-inch equivalents per cu ft of checkerwork, or 35-70 lb. Heating surface may total 2.95-5.25 sq ft per cu ft of checkerwork, but only part of this is effective, ranging 2.6-3.8 sq ft per cu ft and averaging about 3.5. In the common designs, this effective surface may usually be taken as approximately the direct flue surface plus one-half of the indirect flue surface.

Free flue area down through the checkers may run 33-56 per cent of the total horizontal area of the checkerwork, depending on checker construction. Checker flue areas on one end of the furnace usually total 1.5-2.0 sq ft or more per ton of furnace capacity. In two-pass arrangements, this figure is approximately .75 sq ft per ton in the first pass and .42 sq ft per ton in the second.

Waste gas velocities through checkerwork flues may vary from 4-6 fps at the top to 2-3 fps at the bottom. A mass-velocity is perhaps more generally used in regenerator calculations, with some designers using .06-.065 lb of waste gas per sec per sq ft of flue area. All of these velocities are approximately doubled in two-pass checker arrangements.

During an average cycle, checker brickwork averages 250-350 F lower than the waste gas temperature, and incoming air temperature averages about the same amount under that of the brickwork. Overall mean temperature difference, from waste gas to air, averages about 600-650 F. The overall heat transmission coefficient (from gas to air) in regenerators averages 1.8-1.9 Btu per hr per sq ft of heating surface per degree F, increasing or decreasing with the velocity of the gases through the checkerwork.

## TABLE IV

### Design Details of Some Open Hearth Furnaces

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Capacity, net tons | 170 | 170 | 215 | 225 | 225 |
| **Bottom construction** | | | | | |
| Ground magnesite, in. | 11 | 19 | 18 | 20 | 15 |
| Magnesite brick, in. | 9 | 4½ | ..... | 9 | ..... |
| Chrome brick, in. | 2½ | 4½ | 13½ | ..... | 12 |
| Fire clay brick, in. | 13½ | 7 | 4½ | 11½ | 9 |
| Sand, loam, ore, in. | ..... | 2½ | 1 | ..... | ..... |
| Insulation, in. | ..... | 3½ | ..... | ..... | 3½ |
| **Bottom steel** | | | | | |
| Longitudinal I-beam, size, in. | 27 | 18 | 24 | 12 | 24 |
| Longitudinal I-beam, spacing, in. | 18 | 20 | 18 | 8 | 21 |
| Cross beam size, in. | 15 | 15 | 12 | 12 | 12 |
| Cross beam spacing, in. | 24 | Adjacent | 24 | Adjacent | 18 |
| Bottom plate thickness, in. | ¾ | ..... | 1 | ¾ | ¾ |
| Total bottom loading, psi | 1726 | 1593 | ..... | 2200 | 1677 |
| **Roof** | | | | | |
| Span, ft-in. | 19-6 | 20-3 | 19-11 | 20-3 | 22-5½ |
| Thickness, in. | 13½ | 18 | 13½ | 12 | 18 |
| Thickness of ribs, in. | 16 | 22½ | ..... | 18 | 22½ |
| Width of ribs, in. | 9 | 6¾ | ..... | 6¾ | 6¾ |
| Spacing of ribs | 36 | 27 | ..... | 24¾ | 30 |
| Included angle, deg-min | 60-0 | 58-30 | 78-55 | 51-30 | 51-0 |
| Roof arch radius, center of furnace, ft-in. | ..... | ..... | 15-7 | 23-4⅛ | 23-3⅝ |
| Roof arch radius, throat, ft-in. | ..... | ..... | 15-7 | 16-5⅜ | 16-2⅜ |
| Roof arch radius, end of furnace, ft-in. | ..... | 18-4½ | 15-7 | 18-7⅛ | 21-4⅞ |
| Roof arch rise, center of furnace, in. | 24 & 33⅝ | 27½ & 38½ | 30 & 48 | 24 & 32 | 36 |
| Roof arch rise, throat, in. | 24 | 24 | 30 | 9⅜ | 18 |
| Roof arch rise, end of furnace, in. | 24 | 24 | 30 | 21 | 27 |
| Buckstay spacing, ft-in. | 8-9 | 9-0 | 8-9 | 7-11¼ | 8-7⅝ |
| Weight per buckstay section, lb | 24,500 | 30,645 | ..... | 24,000 | 23,980 |
| Span of skewback between buckstays, ft-in. | 6-3 | 6-1 | 5-9 | 5-7¼ | 7-11¼ |
| Type of buckstays | ..... | Two 5x15 in. slabs | Two 5x15 in. laminated slabs | Two 5x15 in. slabs | Two 6x15 in. slabs |
| **Backwall** | | | | | |
| Type | Sloping | Sloping | Semi-sloping | Sloping | Sloping |
| Height, foreplate to skewback, ft-in. | 3-9⅞ | 4-5 | 4-6½ | 4-2½ | 5-0 |
| Brick thickness, in. | 13½ | 13½ | 13½ | 13½ | 20 |
| Granular material, thickness | 6 | 4 | 6 | 6 | 4 |
| **Front wall** | | | | | |
| Height, foreplate to skewback, ft-in. | 5-1½ | 5-4 | 5-9½ | 4-1 | 5-1 |
| Number of doors | 5 | 5 | 5 | 5 | 5 |
| Height of doors, ft-in. | 3-9 | 3-9 | 4-0 | 3-2 | 4-3 |
| Width of doors, ft-in. | 4-0 | 4-3 | 4-0 | 3-6 | 5-1 |
| **Lengths** | | | | | |
| Bath, ft-in. | 46-0 | 46-0 | 47-0 | 40-6 | 52-0 |
| Furnace, overall, ft-in. | 86-3 | 78-0 | 82-7 | 68-6 | 87-0 |
| Roof, horizontal end section, ft-in. | 8-3 | 6-6 | ..... | 4-6½ | 9-6 |
| Roof, down-slope, ft-in. | 10-6 | 8-6 | 14-6½ | 9-10⅜ | 8-0 |
| Roof, up-slope, ft-in. | ..... | 9-0 | ..... | 7-11¼ | ..... |
| Roof, horizontal main section, ft-in. | 48-9 | 30-0 | 53-6 | 23-9¾ | 52-0 |
| Throat and bank, air, ft-in. | 18-7½ | 13-0 | 8-0 | 12-6 | 15-4 |
| Throat and bank, gas, ft-in. | 12-6 | 6-0 | 5-6 | 5-0 | 6-3 |
| Slope of throat bottom | 4:12 | 2:12 | 6:12 | 1⅝:12 | 7:12 |
| **Widths** | | | | | |
| Bath, ft-in. | 15-0 | 15-0 | 15-0 | 15-6 | 17-7½ |
| Throat, ft-in. | 16-0 | 11-0 | 15-10½ | 10-0 | 13-0 |
| Furnace end, inside, ft-in. | 16-0 | 16-0 | 15-10½ | 15-6 | 18-0 |
| **Heights** | | | | | |
| Foreplate to roof crown, center of furnace, ft-in. | 7-1½ | 6-7½ | 8-2 | 6-10½ | 8-2 |
| Foreplate to roof crown, knuckle, ft-in. | 7-1½ | 5-3 | 8-6 | 6-1½ | 8-2 |
| Foreplate to roof crown, end, ft-in. | 11-10½ | 11-0 | 11-6 | 9-8 | 11-6 |
| Depth, foreplate to refractory, in. (max) | 36 | 32 | 35 | 48 | 48 |
| Depth, foreplate to bottom plate, in. | 72 | 73 | 72 | 88½ | 72 |
| Regenerator floor to foreplate, ft-in. | 22-7½ | 23-0 | 34-8 | 20-5½ | ..... |
| **Slag pockets (each end)** | | | | | |
| Length, ft-in. | 17-6 | 17-6 | 17-9 | 15-0 | 24-0 |
| Height, ft-in. | 10-6 | 11-0 | 10-2 | 12-3 | 14-4 |
| Width, large, ft-in. | 7-0 | 6-6 | 15-10½ | 11-6 | 16-3 |
| Width, small, ft-in. | 5-0 | 5-6 | ..... | ..... | ..... |
| Volume, large, cu ft | 1193 | 1168 | 2850 | 1897 | 5600 |
| Volume, small, cu ft | 872 | 1004 | ..... | ..... | ..... |

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Fantails** | | | | | |
| Length, ft-in. | 4-10¼ | 9-0 | 10-0 | 8-4 | 14-6 |
| **Regenerators (each end)** | | | | | |
| Length, ft-in. | 28-4 | ..... | 23-4 | 38-7¾ | 30 |
| Height, ft-in. | 16-0 | ..... | 25-2 | 12-1 | 25 |
| Width, large, ft-in. | 16-0 | ..... | 14-1 | 21-6 | 13-4½ |
| Width, small, ft-in. | 9-9 | ..... | 9-1 | ..... | 13-4½ |
| Volume, large, cu ft | 7260 | ..... | 8250 | 10,025 | 10,000 |
| Volume, small, cu ft | 4425 | ..... | 5360 | ..... | 10,000 |
| Checkerwork volume, cu ft | ..... | ..... | 8650 | ..... | 11,200 |
| **Cross-section areas, sq ft** | | | | | |
| At center of furnace | 103.1 | 125.6 | 136.5 | 122.4 | 121.0 |
| At knuckle | 58.1 | 55.3 | 103.2 | 53.5 | 88.6 |
| Fuel inlet port | ..... | 4.9 | ..... | ..... | ..... |
| Minimum between knuckle and end wall | 67.6 | 74.7 | 56.5 | 66.2 | 57.6 |
| Over uptakes at greatest roof elevation | 77.6 | 66.1 | 82.0 | 77.4 | 76.2 |
| Air uptakes | 42.6 | 43.8 | 86.0 | 58.5 | 96.0 |
| Fuel uptake | 21.3 | 6.9 | ..... | ..... | ..... |
| Combined downtakes | 63.8 | 48.8 | 86.0 | 58.5 | 96.0 |
| Vertical sectional area, large | 68.2 | 66.6 | 147.5 | 126.5 | 132.0 |
| Vertical sectional area, small | 49.8 | 57.3 | ..... | ..... | ..... |
| Fantail, slag pocket end, large | 68.2 | 47.2 | 72.5 | 45.0 | 113.6 |
| Fantail, slag pocket end, small | 49.8 | 40.8 | ..... | 22.5 | ..... |
| Fantail, regenerator end, large | 52.6 | 76.8 | 69.5 | 55.0 | 78.0 |
| Fantail, regenerator end, small | 32.4 | 60.3 | ..... | 27.0 | ..... |
| Regenerator flue, large | 49.0 | 40.3 | 28.0 | 33.7 | 33.4 |
| Regenerator flue, small | 24.0 | 35.0 | 21.9 | ..... | 33.4 |
| Stack flue | 54.0 | ..... | 34.5 | 35.3 | 45.9 |
| Stack | 46.1 | ..... | 44.1 | 40.1 | 36.7 |
| **Miscellaneous data** | | | | | |
| Kind of fuel | Oil | Producer gas | Oil | Coke oven gas | Oil |
| Btu per net ton of steel | 4,020,000 | 4,050,000 | 3,470,000 | 4,360,000 | 3,260,000 |
| Lb of steel produced per hr per sq ft of hearth | 53 | 42.7 | 44.6 | 45.5 | 45.0 |
| Air supply | Natural | Forced | Forced | Forced | Forced |

For maximum efficiency of regeneration, and consequently, of furnace performance, infiltration through the walls of regenerators, slag pockets and furnace ends must be kept to a minimum. Such infiltration may result in only 50 per cent or less of the combustion air passing through the checkers on the incoming end, while similar infiltration on the outgoing end reduces checker temperature and cuts down draft. All of these walls should be well sealed, and, where the temperature and refractory permits, insulated as well. Furnace construction should be tight enough so that the volume of exit gases does not increase more than 40 per cent (the lower the better), as determined by simultaneous gas analyses at the end of the furnace and in the exit flues from the regenerators.

Dust deposits in the regenerators may total 2-12 lb per ton of steel produced, depending on the effectiveness of the slag pockets, checker flue size, and type of fuel. This deposit analyzes 70-85 per cent iron oxide, 2-10 per cent silica, 3-11 per cent lime and magnesia, up to 7 per cent alumina, and a little manganese oxide. To maintain regenerative efficiency, checkers may be blown by a compressed air or steam lance, at intervals varying from one day to two or three weeks. Steam nozzles may also be built into the bottom of regenerators and flues, for use while the furnace is operating, and more recently, vacuum systems have been developed for the removal of dust and debris when the furnace is down.

Regenerator flues total 22-72 sq ft in sectional area for each end of the furnace. This total area is divided between the two sections of the regenerator in the same proportion as the regenerator division. Per ton of furnace capacity, this flue area may range .2-.5 sq ft. Recent installations show about .3 sq ft per ton. With the sliding damper type of valves now favored, the valve areas are about the same as the flue areas.

The combined stack flue usually has a sectional area of 60-70 per cent of the regenerator flue area, while stack area runs .75-1.25 times that of the stack flue.

In Table V, a typical successful furnace is analyzed. Gas flow is gradually increased in accordance with infiltration as usually found, beginning with 10 per cent excess air over the bath and gradually stepping up to 60 per cent at the stack. Temperatures are assumed in accordance with those found in practice. It should be

**Figure 9 — The bulkheads of these regenerators contain apertures through which lances may be used to blow dust from the checkerwork.**

**TABLE V**

**Gas Flow in a 200 Ton Open Hearth Furnace**

**(Fuel input per hr — 450 gal average, 600 gal maximum)**

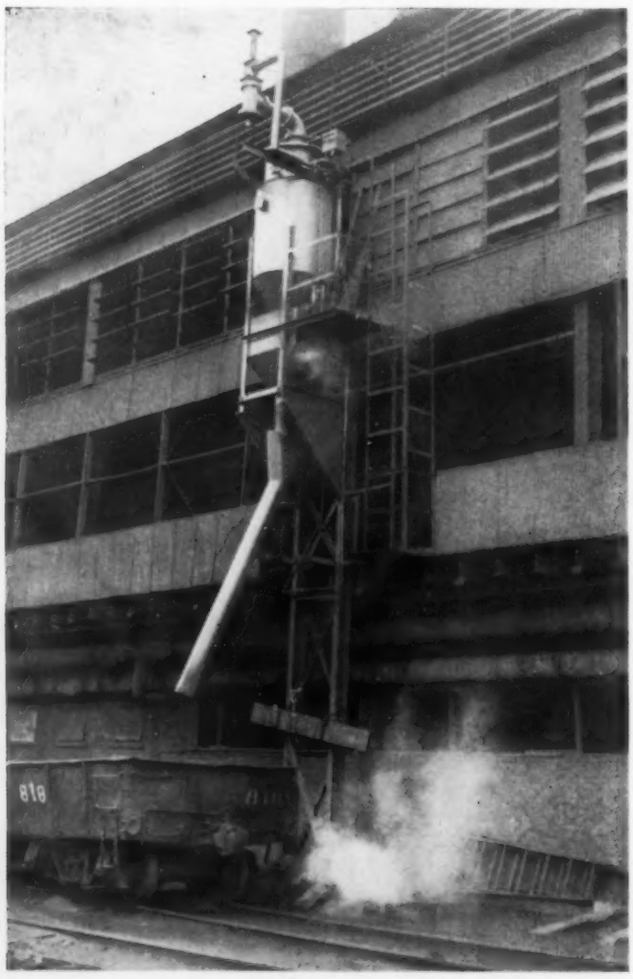
| | Volume at 60 F, cu ft per sec | Area, sq ft | Velocity, fps at 60 F | Temperature, F | Volume factor at temperature | Actual velocity, fps, with 450 gpm | Actual velocity, fps, with 600 gpm |
|---|---|---|---|---|---|---|---|
| Air through checkers | 133 | 400 | .33 | 200-1800 | 1.3-4.3 | .43-1.42 | .57-1.89 |
| Air in uptakes | 167 | 86 | 1.95 | 2000 | 4.7 | 9.2 | 12.3 |
| Air through smallest area in furnace end | 184 | 56.5 | 3.25 | 3000 | 6.6 | 21.5 | 28.7 |
| Air through throat | 184 | 109. | 1.69 | 3200 | 7.0 | 11.8 | 15.7 |
| Gas in furnace laboratory | 200 | 136. | 1.47 | 3500 | 7.6 | 11.2 | 14.9 |
| Gas through throat | 200 | 109. | 1.83 | 3200 | 7.0 | 12.8 | 17.1 |
| Gas through smallest area in furnace end | 200 | 56.5 | 3.55 | 3100 | 6.8 | 24.1 | 32.2 |
| Gas in downtakes | 209 | 86 | 2.44 | 3000 | 6.6 | 16.1 | 21.5 |
| Gas in slag pocket | 225 | 147 | 1.53 | 2700 | 6.1 | 9.3 | 12.4 |
| Gas through fantail | 234 | 69.5 | 3.46 | 2600 | 5.9 | 20.4 | 27.2 |
| Gas through checkerwork | 242 | 400. | .60 | 2500-1100 | 5.7-3.0 | 3.42-1.8 | 4.56-2.4 |
| Gas through regenerator flues | 250 | 62 | 4.0 | 1100 | 3.0 | 12.0 | 16 |
| Gas through stack flue | 258 | 45 | 5.7 | 1050 | 2.9 | 16.5 | 22.0 |
| Gas through stack | 267 | 40 | 6.7 | 1000 | 2.8 | 18.7 | 24.9 |

noted that the smallest sectional area in this furnace lies between the throat and the end wall. Many designers object to a constriction of this type.

*Water cooling*—Many places on open hearth furnaces are water-cooled, including doors and frames, main buckstays on both sides of the doors, and in some cases the front skewback if archless door frames are used. Pipe coolers are built into monkey walls and in the upper portion of the bridge walls. A cooler may also be built into the end wall at the uptakes. The fuel port or doghouse is water-cooled, as are oil burners.

Water from these various points flows into two or four collecting boshes. For economy reasons, it is desirable to reuse this water, perhaps in the reversing valves and stack damper.

**Figure 10 — Tank and vacuum unit of a system installed to handle dust and debris from open hearth furnaces during the rebuilding period.**



*Draft*—Approximately half of the open hearth furnace installations operate with natural draft on the incoming air and on the exit gases. Air is drawn into the flues of the incoming end of the furnace by the stack action of the regenerators and furnace uptakes. As might be expected, as the temperature in these sections drops gradually during this half of the reversal period, the quantity of air pulled in gradually decreases. Hence, the use of forced draft fans to supply air to the flues is meeting more favor. Such fans should have a capacity of about 15,000 cu ft of air per million Btu of maximum fuel input, at a pressure of about 3 in. water. A venturi tube inlet is desirable, as well as a regulating valve in the discharge line. With two-pass checkers, forced draft fans are essential as well as induced draft fans.

On the exit end of the furnace, natural draft is provided by the furnace stack, which must have sufficient pull to overcome the counter-pull of the furnace downtakes and regenerators. Stacks range 6-7 ft in diameter and 150-225 ft in height.

If waste heat boilers are installed an induced draft fan is necessary to overcome the draft loss through the boiler. These fans should have a capacity of about 40,000 cu ft, at 7-10 in. water column and 550 F, per million Btu of fuel input to the furnace.

Waste heat boilers, which may be either fire-tube or water-tube types, contain 35-65 sq ft of heating surface per ton of furnace capacity, running to the low side for fire-tube boilers and to the higher side for water-tube units. Steam production ranges 900-1300 lb of steam per ton of steel produced. Approximately half of the open hearth furnaces in the United States are equipped with waste heat boilers.

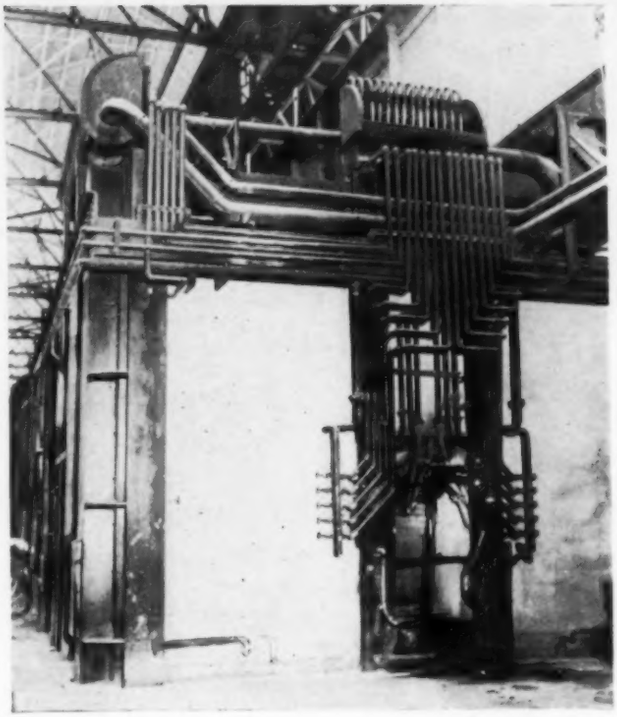


**Figure 11 — This view of the end of a furnace shows some of the water-cooling piping and collecting boshes.**

*Tilting open hearth furnaces*, once quite popular in the steel industry, are seldom installed now, except in the case of rather specialized metallurgical processes, usually involving some form of duplexing. The most recent tilting installations have been for use in producing a purified molten steel charge for subsequent refining in electric arc furnaces.

Tilting furnaces, usually of 200-250 ton holding capacity, are designed very much the same as stationary furnaces, except that the main hearth section, between the knuckles, is arranged to tilt between the two stationary port sections. The tilting section, with water-cooled chills at each end, is carried on longitudinal box section girders which are supported by two steel rockers. These rockers in turn bear on rollers, so that, through the action of motor-driven screws, the furnace may tilt through a range of about 30 degrees forward for tapping and 10-12 degrees backward for slagging.

## REFRACTORIES

The requirements imposed upon the refractories of the open hearth furnace are varied and severe. The hearth must be highly refractory, and must withstand erosion by the molten slag and bath. Walls are subject to high temperature flames, and to slag and metal splashes. Roofs must have sufficient strength to withstand arch stresses at high temperatures, and in some cases are subject to some splashing. The ends of the furnaces must resist the impact and scouring actions of the hot gases, in which are entrained particles of slag, iron oxide, etc.

To meet these conditions, a more or less standard practice was developed. The basic furnace bottom is a composite of insulation, fire clay brick, chrome or magnesite brick, and ground magnesite, as previously described. Front walls are of silica or basic brick, and back walls are generally a composite of silica or fire clay brick and chrome or magnesite brick, covered with magnesite bottom material. Roofs and ends are principally of silica brick, with some magnesite brick in the downtake bulkheads and doghouse. Slag pockets are built of silica brick, while regenerators and checkerwork are generally built of fire clay brick, although some installations use silica brick on the top portion of the regenerators, where temperatures are high. Fire clay brick is used in flues and stacks.

Since silica brick is acidic in nature, it is vulnerable to attack by the slag and dust of basic open hearth practice. Hence, there has been considerable activity in recent years toward the development of basic refractory construction. This development began with the spooning of chrome ore on the front walls above the bank to prolong refractory life. Entire basic front walls were found to last as long as an entire furnace campaign. Next came basic construction in parts of the

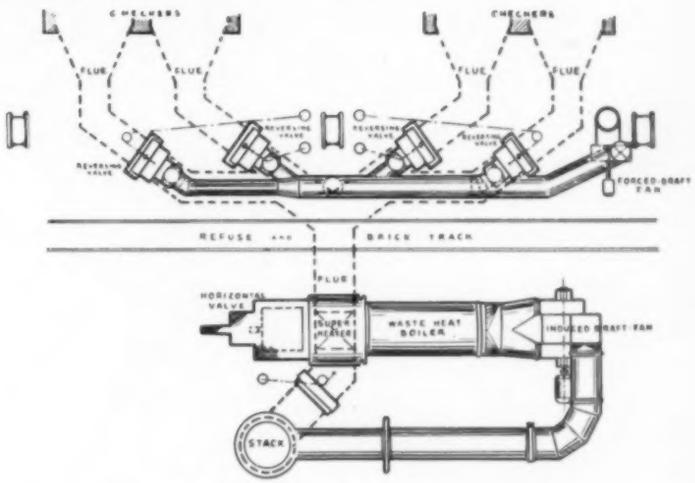



**Figure 12 and 13 — The sketch above shows the general arrangement of air piping in a forced draft installation, as well as the layout of waste gas flues, waste heat boiler, etc. The photograph below shows part of the same installation.**

**Figure 14 — This tilting furnace is the most recent installation of its type. Rated at 250 tons capacity, it was built to provide a purified molten steel charge for subsequent refinement in electric arc furnaces.**

furnace ends, and then entire basic ends, where basic construction has shown a total life of more than three times that of silica brick construction, with fewer intermediate repairs. Basic construction has also led to changes in the design of furnace ends so that downtake areas were materially increased.

The success of basic furnace ends, front walls and back walls, finally led to the all-basic furnace. Experimental all-basic furnaces have shown substantial increases in furnace life, and the experience gained has led to gradual improvement that will extend these increases even farther. Since basic construction is much more expensive than the conventional construction. greater life and increased furnace availability are of course necessary to justify the change.

Table VI gives analyses of various refractories commonly used in open hearth furnaces.

Silica brick, which forms the greater part of the open hearth structure, expands and contracts to a marked degree in the temperature range between 450 F and 1600 F. Hence, it is quite susceptible to spalling in that range, and should not be allowed to pass through that range too rapidly. The newer the brick, the greater the tendency to spall.

Silica brick can be made to withstand greater impact by the use of higher pressures in their manufacture. The tendency to spall can be reduced by increasing the grain size in the brick, and by burning the brick longer at higher temperatures. Resistance to slag penetration is improved by decreasing grain size. Hence, the characteristics of silica brick should vary according to its application. Well-burned silica brick has a lower specific gravity (2.28-2.33) than poorly burned brick (2.33-2.65). Silica brick work weighs 90-110 lb per cu ft, averaging about 105.

Fire clays from which fire clay brick is made may be of flint or plastic types, according to their physical pro-

**TABLE VI**

**Analyses of Refractories**

| | $SiO_2$ | Iron oxides | $Al_2O_3$ | CaO | MgO | Alkalies | $H_2O$ | Ignition loss | $Cr_2O_3$ | Fusion point, F |
|---|---|---|---|---|---|---|---|---|---|---|
| **Acid** | | | | | | | | | | |
| Silica brick | 94-97 | .5-1.5 | .5-1.5 | 1.5-2.0 | .1-.5 | .25 | ..... | ..... | ..... | 3000-3200 |
| Fire clay (plastic) | 48-73 | .5-8.0 | 15-45 | .1-1.2 | .1-1.5 | .2-3.0 | 6-14 | ..... | ..... | ..... |
| Fire clay (flint) | 40-63 | .1-3.0 | 21-47 | .1-1.0 | .1-.5 | .5-3.0 | 6-14 | ..... | ..... | ..... |
| Fire clay brick | 50-65 | 1.0-3.0 | 20-45 | .1-1.5 | .1-1.0 | .1-2.0 | ..... | ..... | ..... | 2700-3100 |
| **Basic** | | | | | | | | | | |
| Magnesite (raw) | 1-5 | .3-4.0 | .2-3.0 | .5-3.0 | 38-45 | .2-1.0 | .5-1.5 | 43-51 | ..... | ..... |
| Magnesite (burnt) | 2-9 | .5-8.0 | .5-5.0 | 1.0-6.0 | 76-91 | .5-2.0 | .1-.5 | .1-.5 | ..... | 3950-5070 |
| Magnesite brick | 1-5 | 1-7 | 1-4 | .2-1.0 | 85-94 | .2-1.0 | ..... | .1-.3 | ..... | 3300-3800 |
| Dolomite (raw) | .3-1.0 | .5-4.0 | .5-3.0 | 30-34 | 20-23 | .2-1.0 | .5-1.0 | 46-48 | ..... | ..... |
| Dolomite (single burnt) | .7-1.5 | .5-6.0 | .5-1.0 | 40-42 | 28-30 | .3-1.5 | ..... | 28-30 | ..... | ..... |
| Dolomite (double burnt) | 1-2 | 1-8 | 1-6 | 52-55 | 33-36 | .5-2.0 | ..... | 1-3 | ..... | ..... |
| Dolomite (synthetic) | 1-6 | 1.5-8.0 | 1-5 | 45-55 | 28-38 | .5-2.0 | ..... | .4-1.0 | ..... | ..... |
| **Neutral** | | | | | | | | | | |
| Chrome ore | 2-10 | 10-22 | 8-30 | 1-3 | 8-20 | ..... | ..... | 2-3 | 30-56 | 3450-3950 |
| Chrome brick | 2-6 | 11-17 | 15-33 | 1-5 | 10-18 | ..... | ..... | ..... | 30-45 | 3700 |
| Olivine | 39-43 | 5-17 | 0-1.0 | 0-2.0 | 44-52 | ..... | ..... | ..... | ..... | 2600 |

perties, and may vary widely in composition. A mixture of clays, predicated upon experience, is generally used for brick manufacture.

Fire clay brick does not have any serious tendency to spall, and this tendency is minimized by a coarse grind of the raw material and by soft burning. On the other hand, resistance to fluxing and slagging is increased by greater density and harder burning. The specific gravity of fire clay brick ranges 2.6-2.8 and up to 3.0 for the high alumina types. Fire clay brickwork weighs 113-114 lb per cu ft, with an average of about 125.

The chief basic refractories are magnesite and dolomite. Magnesite is used in granular and brick forms. Its high fusion point makes it a fine refractory, but its low strength and pronounced tendency to spall limits its applications. Both strength and resistance to spalling are improved by enclosing the brick in a metal container, forming a metal-clad brick. Magnesite brick has a specific gravity of 3.4-3.6, and brickwork averages about 165 lb per cu ft.

In granular, dead-burned form, both magnesite and dolomite are used for furnace bottoms, and dolomite, in combined synthetic form, has been developed to a point where it is excellent for repairing furnace bottoms. Raw dolomite, usually crushed to a uniformly small size of about ¼ in., is used largely for banking up doors and slag line repairs. Heat and time are required to calcine raw dolomite and sinter it in place. Single-burnt dolomite may be used for most bank repairs, sized from dust to 2 in. or more. It burns into place more rapidly than the raw material. Double-burnt dolomite, almost completely calcined and containing approximately 6-8 per cent iron oxide is used for rapid bonding on banks and bottoms.

Among the more common neutral refractory materials are chrome ore, chrome brick and olivine rock. Chrome ore and olivine rock are used in some cases for furnace hearth banks above the slag line.

Chrome brick is highly refractory, and has better resistance to spalling than magnesite brick. The neutral nature of chrome brick permits its use in contact with either acid or basic refractories, and it is used as a partition between the two. Chrome brickwork weighs about 150 lb per cu ft.

The quantity of brick required for an open hearth furnace varies with the capacity of the furnace, with further substantial variations in requirements for bottoms, ends, checkers, flues and stack, depending on design and layout. For one modern 225-ton furnace, the brick count is as shown in Table VII.

If basic ends or all-basic construction are used, the refractory requirements will be quite different. Table VIII gives a comparison of refractories for the construction of a 150-ton open hearth furnace by the three types of construction.

Furnace life depends on design, materials of construction, and rate of driving. The length of a furnace campaign is determined by the general condition of the refractories, particularly the furnace roof. Roofs last 150-400 heats, the life lengthening in smaller furnaces. On large furnaces, roofs that have been properly installed and cared for should last 250 heats. Port construction lasts about 100 heats without cooling, and up to 400 heats with complete cooling. Sidewalls should last about as long as the roof. Basic construction has given extended life in almost every application, and this development may expand materially. Regenerators may last 500-1500 heats, but checkerwork may require cleaning every 200-400 heats, and may require partial rebuilding every 400 heats, at which time about 25 per cent of the brick is renewed.

**TABLE VII**

**Brick Count for 225 Ton Furnace**

| | 9 in. equivalents | Lb | Board ft |
|---|---|---|---|
| **Furnace** | | | |
| Silica brick | 157,200 | | |
| No. 1 fire clay brick | 32,200 | | |
| Chrome brick | 31,800 | | |
| Insulating brick | 4,100 | | |
| Insulating concrete | | 2,500 | |
| **Slag pockets** | | | |
| Silica brick | 218,800 | | |
| No. 1 fire clay brick | 66,900 | | |
| No. 2 fire clay brick | 12,400 | | |
| Insulating brick | 6,300 | | |
| Insulating concrete | | 6,600 | |
| Block insulation | | | 9,800 |
| **Regenerators** | | | |
| No. 1 fire clay brick | 277,300 | | |
| No. 2 fire clay brick | 11,000 | | |
| Insulating concrete | | 43,400 | |
| Block insulation | | | 20,050 |
| Checkers, 58,100 pieces, 18 in.×6 in.×3 in. | 187,000 | | |
| **Flues** | | | |
| No. 1 fire clay brick | 111,700 | | |
| No. 2 fire clay brick | 11,700 | | |
| Insulating concrete | | 78,250 | |
| **Stack and base** | | | |
| No. 1 fire clay brick | 4,500 | | |
| No. 2 fire clay brick | 48,300 | | |
| | **9 in. equivalents** | **Lb** | **Board ft** |
| **Recapitulation** | | | |
| Silica brick | 376,000 | | |
| No. 1 fire clay brick | 492,600 | | |
| No. 2 fire clay brick | 83,400 | | |
| Checkers (No. 1 fire clay) | 187,000 | | |
| Chrome brick | 31,800 | | |
| Insulating brick | 10,400 | | |
| Insulating concrete | | 130,750 | |
| Block insulation | | | 29,850 |
| | 1,181,200 | 130,750 | 29,850 |

Refractory consumption in the open hearth furnace averages somewhat as follows:

| | Lb per net ton of steel |
|---|---|
| Silica brick | 30 |
| Fire clay brick | 15 |
| Magnesite brick | 4 |
| Chrome brick | 1 |
| Dolomite | 25-80 |
| Fire clay | 5-15 |
| Chromium ore | 1- 3 |

In addition to this usage, approximately 30 or 35 lb of refractories are used in ladles and other pouring pit applications for every ton of ingots.

As previously mentioned, basic construction lengthens furnace life considerably. Basic roofs are lasting 300-500 heats on large furnaces, and basic ends indicate a life better than three or four times that of silica brick construction.

**TABLE VIII**

**Approximate Brick Requirements for a 150 Ton Open Hearth Furnace**
**(9 in. equivalents)**

| Section of furnace | Silica furnace | Basic end furnace | All-basic furnace |
|---|---|---|---|
| Roof | 30,000 Silica | 30,000 Silica | 24,000 Basic |
| Front wall | 3,000 Basic | 3,000 Basic | 3,000 Basic |
| Back Wall | 5,000 Basic | 5,000 Basic | 5,000 Basic |
| Monkey and bridge walls | 7,000 Basic | 7,000 Basic | 7,000 Basic |
| Bottom | 10,000 Fire clay<br>35,000 Basic | 10,000 Fire clay<br>35,000 Basic | 10,000 Fire clay<br>35,000 Basic |
| Uptakes from foreplate level to roof | 30,000 Silica | 18,000 Basic | 18,000 Basic |
| Slag pockets up to foreplate level | 150,000 Silica | 90,000 Basic | 90,000 Basic |
| Fantail arches | 13,000 Fire clay | 10,000 Fire clay | 10,000 Fire clay |
| Checker chambers | 250,000 Fire clay | 250,000 Fire clay | 250,000 Fireclay |
| Checkers | 125,000 Fire clay | 125,000 Fire clay | 125,000 Fire clay |
| Flues | 120,000 Fire clay | 120,000 Fire clay | 120,000 Fire clay |
| Stack | 50,000 Fire clay | 50,000 Fire clay | 50,000 Fire clay |
| Totals | 828,000 | 763,000 | 757,000 |

| Recapitulation | Silica furnace | Basic end furnace | All-basic furnace |
|---|---|---|---|
| Basic | 50,000 | 158,000 | 182,000 |
| Silica | 210,000 | 30,000 | ..... |
| High duty fire clay | 398,000 | 405,000 | 405,000 |
| Low or intermediate duty fire clay | 170,000 | 170,000 | 170,000 |
| Totals | 828,000 | 763,000 | 757,000 |

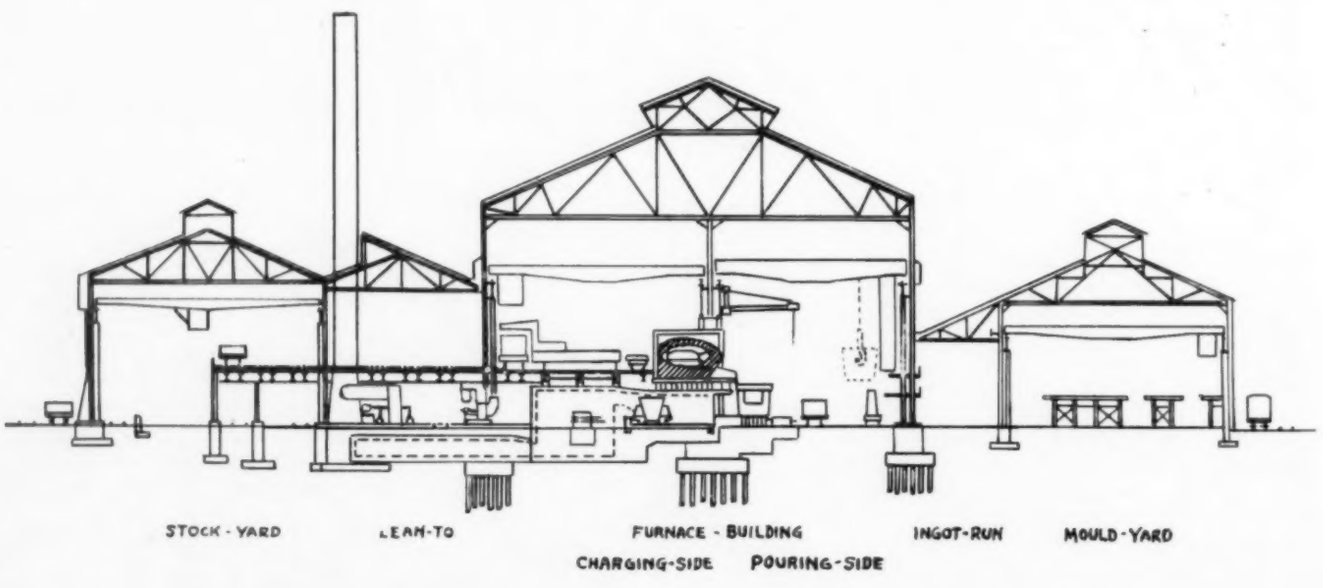
## PLANT LAYOUT AND BUILDINGS

An open hearth plant may consist of six to nine buildings in various arrangements. Older plants may have only three of these buildings adjacent to each other, with the other units placed separately. The most recent installations, however, consist of the following buildings laid parallel and adjacent:

*Stockyard*—70-100 ft wide and almost as long as the main open hearth building. Contains 3 or 4 overhead cranes of 10-15 ton capacity, with speeds of 400-450 fpm on the bridge motion, 125-200 fpm on the trolley motion, and 80-100 fpm on the hoist. Magnet operation is required on these units. Preferably has two levels, with upper level even with the open hearth floor, 15-22 ft above ground level. The upper level may have two or three standard gage tracks, while one track is usually placed on the ground level.

*Leanto*—Up to 60 ft wide, and same length as the main building. Usually contains no cranes. May contain stacks, waste-heat boilers, and fans. Railroad tracks may be placed on upper or lower levels, or both. The leanto may also house control equipment, laboratories,

**Figure 15 — Section through the principal buildings of a modern open hearth shop. The elevated tracks in the stockyard are connected to the charging track on the charging floor by suitable cross-overs so as to minimize interference and delay.**



lock rooms, etc., as well as bins for various alloys and materials.

*Charging aisle*—75-85 ft wide, with main building columns on centers of 75-110 ft. One furnace is placed in each bay, and several extra bays may be left at either end of the building for storage and miscellaneous use. An open hearth shop may contain up to 15 furnaces, beyond which it is not efficient to go; 12 furnaces in a row are preferred by most designers. The charging floor carries two to four charging machines of 10-15 ton capacity, and is served by two 100-150 ton overhead cranes for hot metal and miscellaneous use. Modern charging machines have bridge speeds of 400-450 fpm, trolley speeds of about 200 fpm. The peel is elevated by a crank motion with a speed of 12-18 rpm, and is revolved at a speed of 22-36 rpm. Hot metal cranes may have a bridge speed of 250-350 rpm, a trolley speed of 100-150 fpm, and a hoist speed of 12-22 fpm, and they should be equipped with an auxiliary hoist for miscellaneous service. Tracks are provided on the floor for the charging machines, for strings of charging buggies, and perhaps for a hot metal car. There should be sufficient crossovers between the stockhouse and the charging track to eliminate interference in charging. A hot metal or mixer building is usually located at one end of the charging bay.

*Pouring aisles*—70-80 ft wide, and usually the same length as the charging aisle. Some additional length may be required if special pouring facilities are to be installed. Contains two to four ladle cranes, each of ample capacity to hold one ladle full of steel and provided with an auxiliary hoist for miscellaneous use. Ladle crane speeds vary somewhat with their capacity, and usually range 250-300 fpm on the bridge, 100-150 fpm on the trolley and 12-20 fpm on the hoist.

A jib crane of 5-7½ ton capacity is often installed on the tapping side of each furnace to handle runners, ladle additions, etc.

Two to four pouring platforms are usually installed at a height slightly below the top of the ingot mold standing on its buggy ready for filling. The charging and pouring bays are built as separate bays of a single building.

Under each furnace between its regenerator chambers, a short track may be installed between the charging and pouring bays, so that a slag thimble may be moved under the front of the furnace for slag flushing

**Figure 16 — The pouring pit, 70-80 ft in width, is on the yard level, and contains permanent ladle stands at each furnace, as well as pouring platforms, ladle cranes, etc.**

practice and then moved out into the pouring pit for disposal.

Suitable facilities for relining and drying ladles are installed in the pouring pit, with facilities for preparing stopper rods nearby.

*Ingot run*—Up to 40 ft wide, in the form of a leanto. Contains no cranes, but has two railroad tracks. Is essentially a covered runway for handling strings of ingot buggies.

*Mold yard*—70-100 ft wide and somewhat shorter than main building. Contains facilities for dipping or spraying molds, as well as several tracks for drags of mold buggies, paralleled by platforms from which to inspect and clean molds, adjust hot tops, etc. Served by two or three overhead cranes of 25-60 ton capacity.

Other buildings in the open hearth department may include a scrap drop, a cinder yard, and a stripper building. Each of these buildings may be 70-90 ft wide × 200-400 ft long, equipped with suitable crane facilities.

*Materials handling*—As indicated in the foregoing, the brunt of materials handling in the open hearth is borne by overhead cranes, working in conjunction with charging buggies and ingot buggies. In recent installations, more attention has been given to the efficient handling of miscellaneous materials. As an example, in one shop, dolomite is received on the charging floor level

**TABLE IX**

**Lifting Magnet Capacities**

**(Pounds)**

| Class of material | Magnet sizes | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 18 in. | 24 in. | 29 in. | 39 in. | 45 in. | 55 in. | 65 in. | 65 in., deep |
| Skull cracker balls, standard magnets | 2100 | 4000 | 8,000 | 12,000 | 16,000 | 20,000 | 30,000 | 38,000 |
| Skull cracker balls, special pole shoe | 3000 | 6000 | 10,500 | 18,000 | 24,000 | 30,000 | 40,000 | 45,000 |
| Slabs | 3300 | 6500 | 13,000 | 20,000 | 38,000 | 50,000 | 65,000 | 70,000 |
| Machine-cast pig from stock pile | 150 | 275 | 550 | 900 | 1,580 | 2,500 | 3,500 | 4,400 |
| Sand-cast pig from stock pile | 130 | 250 | 430 | 800 | 1,420 | 2,300 | 3,000 | 4,000 |
| Machine-cast pig from railroad car | 130 | 250 | 430 | 800 | 1,420 | 2,300 | 3,000 | 4,000 |
| Sand-cast pig from railroad car | 120 | 225 | 390 | 700 | 1,300 | 2,200 | 2,850 | 3,800 |
| Heavy melting scrap | 150 | 275 | 550 | 900 | 1,580 | 2,500 | 3,500 | 4,400 |
| Plate scrap | 130 | 250 | 500 | 700 | 1,100 | 1,500 | 2,300 | 2,800 |
| Broken scrap | 110 | 200 | 350 | 600 | 1,000 | 1,400 | 1,800 | 2,300 |
| Cast iron bearings | 110 | 200 | 350 | 600 | 1,100 | 1,550 | 2,400 | 2,900 |
| Steel turnings | 50 | 100 | 175 | 300 | 450 | 750 | 1,200 | 1,700 |

**Figure 17 — This view shows a cinder pot car that operates under the furnace between the charging and pouring sides in flush slag practice. The furnace shown here is of tilting type.**

in hopper cars, and is dropped into a number of bins. From here it is carried by belt conveyor and bucket elevator to an overhead bin, and then chuted into the dolomite machine or into boxes for transfer by crane to desired points along the charging floor. Ferro-manganese and ferro-silicon are brought onto the charging floor in gondola or box cars, and unloaded into bins beneath the floor. These materials are then chuted into transfer boxes which are moved by crane to bins behind each furnace. Other alloys are unloaded from trucks or railroad cars into bins in the charging floor leanto. An electric truck moves these materials to a scale, where, after weighing, furnace additions are put into charging boxes and ladle additions are put into drop-bottom boxes which are handled at the furnace by jib crane. Limestone and ore are delivered on the charging floor in hopper cars which discharge into bins located below the charging floor. These materials are chuted into charging boxes on the lower level, which are then shifted by rail up to the charging floor.

## INSTRUMENTS AND CONTROLS

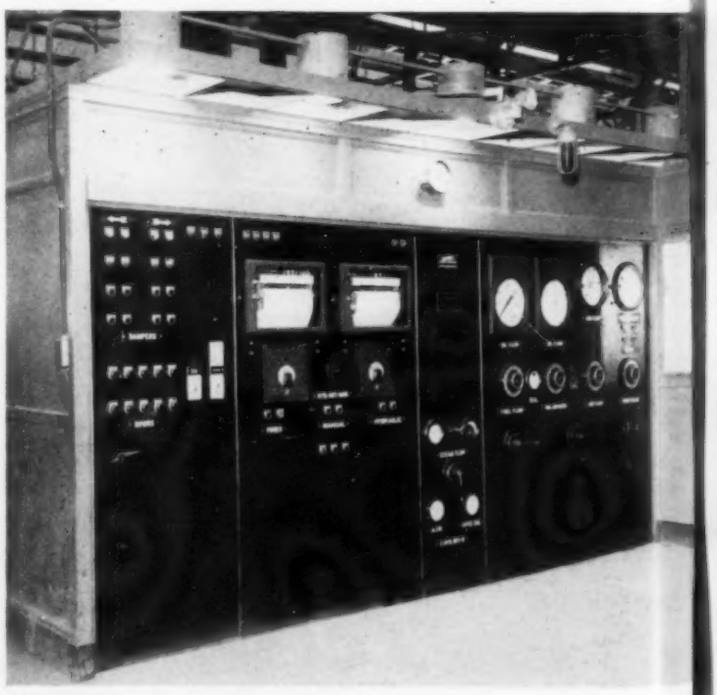
Instruments and controls have been widely applied to open hearth furnaces, and it has been conclusively proven that intelligent use of such equipment does much to improve furnace economy. Perhaps the most useful control equipment that can be applied to an open hearth furnace is furnace pressure control. These units usually consist of a very sensitive gage capable of measuring down to .005 in. water column, combined with means to multiply and transmit impulses from this gage to a power unit which adjusts the damper or regulates the induced draft fan if one is used. The draft gage is connected through the furnace roof midway between the knuckles and balanced against another connection just above the roof, so that the reading is truly comparative.

Low furnace pressure (or excessive stack draft) pulls in cold air through openings in the furnace structure and around doors, and reduces temperatures throughout the furnace. Excessive furnace pressure will shorten refractory life, especially in the front walls. In general, it may be said that furnace pressure should be held as high as possible without endangering the refractories. Actual pressures maintained vary widely with the height of the furnace and local conditions, with values ranging from .05 in. up to .09 in. Furnace pressure is usually recorded, and many operators also want a large, easily-read indicator.

Another type of control widely used is designed to keep regenerator temperatures balanced. This is usually done through base metal thermocouples placed at the bottom of the regenerators and connected to a pyrometer, although radiation units, sighted on the tops of the checkers, are also used. Thus, temperatures at each end of the furnace system are continuously measured. Reversals are usually based on the difference between the temperatures at each end of the furnace, and the controls may be arranged either to set off an alarm when the desired differential is reached, or to automatically reverse the furnace. This type of control may also function on a straight time schedule, or on a combination of time and temperature. A combination often used is one that will operate on temperature differential, on a predetermined maximum time interval, and on a predetermined maximum temperature at the hot end. A chart record of regenerator temperatures is usually kept.

The measurement of roof temperature has also been adopted for many open hearth furnaces. The preferred method is to sight an optical pyrometer through the back wall of the furnace at such an angle that it is cen-

**Figure 18 — This panel board, which carries all instruments and controls for one furnace, forms the front wall of a small house containing control equipment.**



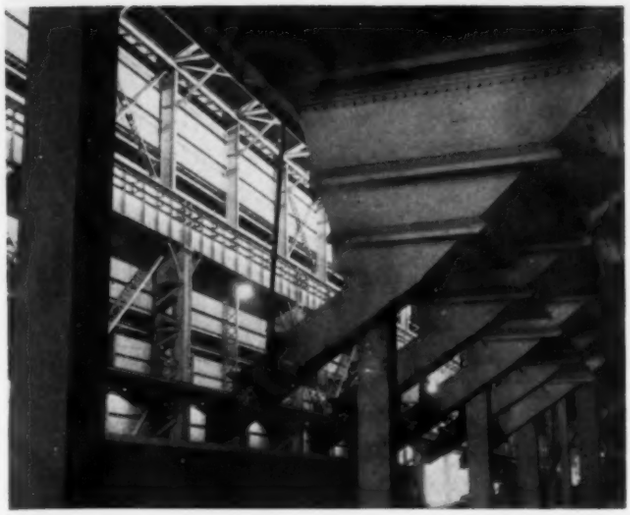


**Figure 19 — These bins for ferro-alloy additions are placed under the charging floor. Material is unloaded into them from railroad cars above, and is chuted into containers which are then moved to the individual furnaces.**

tered on a definite spot in the roof. In some cases, more than one pyrometer are used. The pyrometers may be used with suitable mechanism to actuate an alarm when the roof reaches a predetermined maximum temperature, or the control may be extended to effect automatic reduction of fuel input. Roof temperature should also be recorded.

Fuel-air ratio control has been applied to some furnaces. In the full sense, this control acts automatically to maintain the selected ratio, so that any change in fuel input immediately changes the air supply by adjusting vanes or a valve in the incoming air duct. Many operators, however, prefer merely to measure the fuel flow and air flow with recording meters, using these readings to guide manual adjustments of fuel-air ratio. In many plants, air flow is fixed at the start of the heat and seldom changed thereafter.

Automatic controls may also be used to maintain a constant heat input into furnaces fired with more than one fuel.

Another instrument which, although not widely used at present, offers great possibilities in determining and guiding furnace operation is the radiation tube to measure flame radiation. Greater use of this device will help to speed up open hearth furnace development.

All controls and meters should be provided with easily-read indicators so that the operators can readily see prevailing conditions. Chart recorders should be used on all points on which a round-the-clock watch should be kept. Fuel flow meters should also have totalizing integrators. Instruments and controls that have been applied rather extensively to open hearth furnaces include the following:

1. Furnace pressure controller and recorder.
2. Indicating, recording, integrating flowmeter for coke oven gas or natural gas.
3. Indicating, recording, integrating flowmeter for liquid fuel.
4. Indicating, recording pyrometer for regenerator temperatures, and sometimes for stack temperature. The former may include control for automatic reversal.
5. Indicating, recording pyrometer for roof temperatures, in some cases with automatic control of fuel input.
6. Indicator for fuel-air ratio.
7. Indicating thermometer for liquid fuel temperature.
8. Indicating pressure gages for atomizing steam pressure.

Insofar as possible, all instruments, controls, valves and switches should be mounted on a panel board for each furnace. Modern installations use this board as the front wall of a small house which contains the control equipment. It is desirable to have all panel boards identical.

Good instrument maintenance is essential if maximum benefit is to be obtained. Periodic checks and immediate adjustments are necessary. And equally necessary is the training of operators in the use of controls and instruments. The operator must realize that this equipment is there to assist him, and not to show up his mistakes.

## OPEN HEARTH FUELS

Fuel oil forms the greater part of the open hearth fuel supply, with considerable amounts of tar and pitch, natural gas and coke oven gas, and some producer gas and mixtures of coke oven gas and blast furnace gas. The proportions of each fuel in the industry are about as follows:

| | Per cent |
|---|---|
| Fuel oil | 65 |
| Tar and pitch | 9 |
| Natural gas | 11 |
| Coke oven gas, producer gas and mixed gas | 15 |

*Fuel oil* comes from petroleum. The principal petroleum producing fields in the United States are:

1. Pennsylvania—Appalachian—Light crude oil, paraffin base.
2. Indiana-Illinois—Light crude oil, paraffin base.
3. Mid-continent (Oklahoma, Kansas, and part of Texas)—Medium grades, usually asphaltic base; some paraffin base.
4. Gulf—Heavier grades of asphaltic base crude oils.
5. California—Medium grade oils of asphaltic and mixed base.

Fuel oil may consist of crude oils of such poor quality as to be otherwise valueless, "topped" oils from which the light oils have been removed, residue oil remaining from complete distillation, or blended oils in which any or all of the preceding types are mixed. Residue oils form the greater portion of fuel oils for open hearth use.

Fuel oil analyses usually fall in the following range:

| | Per cent |
|---|---|
| Carbon | 82 -85 |
| Hydrogen | 10 -11 |
| Nitrogen | .02- .40 |
| Sulphur | .5 - 3.0 |
| Oxygen | 1.0 - 3.0 |
| Water | 1.0 - 2.0 |

For metallurgical heating, sulphur should be as low as possible—preferably under one per cent. Moisture should not exceed two per cent, and not more than a trace of sediment should be present.

Other points to be considered in fuel oil specifications include:

*Flash point*—The temperature at which the oil gives

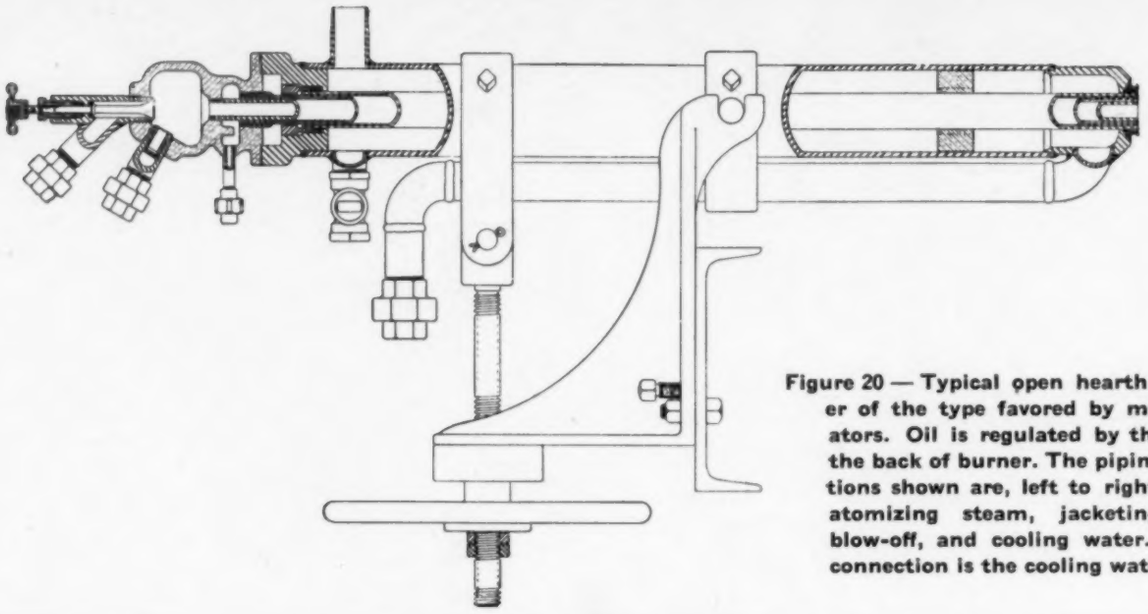


**Figure 20 — Typical open hearth oil burner of the type favored by many operators. Oil is regulated by the valve at the back of burner. The piping connections shown are, left to right, for oil, atomizing steam, jacketing steam, blow-off, and cooling water. The top connection is the cooling water exit.**

off enough vapor to form a momentary flash. This may be 140-370 F, but it must be higher than the temperature required to bring the oil to the desired viscosity.

*Fire point*—The temperature at which the oil burns continuously—usually about 20 degrees higher than the flash point. Excessively high flash and fire points may result in difficulty in ignition.

*Cold test*—The temperature at which the oil congeals and will not flow.

The gravity of oil may be expressed as the conventional specific gravity, or in degrees Baume, as given by direct reading of the Baume hydrometer scale. The two values are connected in the following relations:

For liquids lighter than water:

Degrees Baume = (140 ÷ specific gravity) —130.

For liquids heavier than water:

Degrees Baume = 145— (145 ÷ specific gravity).

The specific gravity of fuel oils generally ranges .90-1.05 (7.5-8.7 lb per gal).

Heating values of fuel oils may be approximated from the following formula:

Gross Btu per lb = 17,680 + 60 × degrees Baume.

Gross Btu per lb = 13,500 C + 60,000 H.

where C = per cent of carbon in oil

H = per cent of hydrogen in oil.

For the usual fuel oils, heating value usually ranges 18,000-19,000 Btu per lb. In general, the higher the specific gravity, the lower the content of the lighter hydrocarbons, and the lower the heating value of the oil per lb. Due to the density, however, the heavier oils have a greater heating value per gallon, and are preferred for open hearth use.

Viscosity of oil is usually expressed in Saybolt seconds. For lighter oils, the scale is generally Saybolt Universal, or the seconds required for 60 cc of oil to flow through the orifice in the instrument at the temperature at which viscosity is being determined. For very heavy oils, the Saybolt Furol standard is used, which equals .1 of the Universal standard.

Viscosity varies with temperature, and in a general, but not definite way, with gravity. Approximate values are as follows:

| Temperature F | Viscosity, Saybolt Universal seconds | | | |
|---|---|---|---|---|
| | 20° Baume | 15° Baume | 12° Baume | 10° Baume |
| 75 | 1450 | .... | .... | .... |
| 100 | 570 | 3000 | .... | .... |
| 125 | 300 | 1150 | .... | .... |
| 150 | 180 | 500 | 2100 | .... |
| 175 | 150 | 300 | 950 | 4000 |
| 200 | .... | 200 | 580 | 1770 |
| 225 | .... | 175 | 400 | 470 |
| 250 | .... | .... | 270 | 300 |
| 275 | .... | .... | 200 | 250 |

For good combustion, fuel oils should be brought to viscosities of 300 or less seconds, Saybolt Universal. Some operators maintain this viscosity at 130 or less. High viscosity oils therefore require high temperatures, but temperatures should not be raised to a point where coking might occur in heaters, etc. With lighter oils, too high a temperature will result in lowered flame radiation.

For perfect combustion, one pound of fuel oil requires about 177 cu ft of air, and produces about 167 cu ft of dry gases and 20 cu ft of water vapor.

Fuel oil systems for open hearth shops are preferably of circulating type, wherein the oil header makes a loop through the shop and back to the storage. The rate of circulation is usually 3 or 4 times the actual consumption.

Oil pumps should produce a steady flow of oil, be capable of performing over a wide range of capacities, and be able to start a flow of relatively cold oil. Reciprocating, double-acting, duplex or simplex pumps are widely used, with oil pressures running 100-200 psi.

Oil is usually passed through a heater on the outlet side of the pump, and in many cases, secondary heaters are provided for the oil flowing to each furnace. Ample heating surface should be provided for the heaviest oils,

with some allowance for fouling of heating surface. Heating surfaces are found ranging 3-10 sq ft per 100 gal of oil per hr. The specific heat of fuel oil is .40-.50 Btu per lb per degree F, and its volumetric coefficient of expansion is .0003-.0004 per degree F.

Oil burners for open hearth use are of the steam-atomizing type, and may range from crude arrangements of pipe fittings to carefully made atomizing devices. Figure 20 shows a burner of the water-cooled, artillery type. Fuel is introduced at the rear end of the atomizer, the amount controlled by a manually operated valve. Steam is introduced into the atomizer, and atomizes the jet of oil, the mixture then flowing out through the central fuel pipe. This pipe is surrounded by a steam jacket to maintain the temperature of the mixture. Cooling water is delivered to the nose of the burner through an outside feed pipe, and leaves at the top of the back end of the burner. Steam for atomizing should be dry, and is supplied to the burner at pressures of 80-150 psi. The amount of steam used for atomization has a marked influence on the flame characteristics, and one series of tests indicate that the best flame conditions are obtained with 2.6-3.1 lb of steam per gal of oil.

In general, burners should be simple, light but rigid, and readily adjustable. Although water-cooling is essential, it should be kept to a minimum.

When oil is burned in combination with coke oven gas or natural gas, a gas pipe must also be introduced into the burner. The gas orifice is usually directly below that of the oil-steam jet, but in some cases, the oil stream may be at the center of the gas stream.

*By-product tar* is used as open hearth fuel only in cases where it cannot be sold for refining at a price exceeding that of fuel oil. The high calorific value, with the great radiating power of its flame, renders it an excellent fuel for the open hearth. Chemical analyses closely approximate that given in Table X.

By-product tar has a specific gravity of 1.1-1.2, weighing 8.9-9.8 lb per gal, and its gross heating value may run as high as 160,000 Btu per gal.

The use of tar is similar to that of fuel oil. It must be heated before burning, and the viscosity varies with temperature somewhat as follows:

| Temperature, F | Viscosity, Saybolt Universal | |
|---|---|---|
| | Raw tar | Topped tar |
| 80 | 1700 | .... |
| 100 | 600 | .... |
| 120 | 250 | .... |
| 140 | 140 | .... |
| 160 | 95 | .... |
| 180 | 60 | 520 |
| 200 | .... | 300 |
| 220 | .... | 180 |
| 250 | .... | 100 |

With raw tar, good results are obtained with a tar temperature of 175 F. Higher temperatures may cause vaporization, while 200 F or above causes a hard coke residue to settle out. About 4.8 Btu are required to raise one gallon one degree F. For topped tar, temperatures should range 225-250 F.

For perfect combustion of one pound of tar, approximately 156 cu ft of air are required, and 151 cu ft of dry gases and 12 cu ft of water vapor are produced.

**Figure 21 — This view of the end of a furnace shows an installation of the type of burner shown in Figure 20.**

*Pitch*, the residue from tar from which certain tar-acid oils have been distilled, is also used to some extent as open hearth fuel. The characteristics of pitch vary widely, depending on the distillation temperature. For use as fuel, pitch should melt at temperatures not much above 100 F. Its specific gravity averages close to 1.25, and its gross heating value is about 16,200 Btu per lb. It is handled much like oil and tar, but a temperature of 280-300 F is essential for good atomization of pitch.

Gaseous fuels used in the open hearth include producer gas, natural gas, coke oven gas, and mixed gas.

*Producer gas* is made by passing a mixture of air and steam through a bed of coal or coke. The oxygen burns the solid fuel to $CO_2$, liberating heat and raising the temperature of the fuel bed. Further contact between the $CO_2$ and the hot carbon reduces some $CO_2$ to CO. The steam reacts with the hot carbon to form $H_2$, CO, and $CO_2$. The hot gases passing on through the upper part of the fuel bed drive off any volatile matter in the fuel. The nitrogen from the air passes through into the gas unchanged.

Almost any fuel can be gasified, with varying results. By far the major portion of producer gas is made from bituminous coal. Best results are obtained from coals of 35-38 per cent volatile matter, with ash not over 5 per cent and sulphur less than 1.5 per cent. The coal should have non-coking characteristics, which points to a high-oxygen coal, having a hydrogen-oxygen ratio of about .5. The ash should have as high a fusion point as possible.

Coal, closely sized, should be fed continuously at a

TABLE X

Comparative Data for Typical Fuels

| | | Oil (gal) | Tar (gal) | Producer gas (cu ft) | Natural gas (cu ft) | Coke oven gas (cu ft) | Blast furnace gas (cu ft) |
|---|---|---|---|---|---|---|---|
| Chemical analysis: (per cent by weight for solids and liquids; per cent by volume for gases.) | S | 1.63 | .75 | ..... | ..... | ..... | ..... |
| | $H_2$ | 10.90 | 6.0 | 11.73 | ..... | 53.0 | 2.0 |
| | C | 84.60 | 86.8 | ..... | ..... | ..... | ..... |
| | $N_2$ | 1.57 | .12 | 56.71 | 1.3 | 3.4 | 59.0 |
| | $O_2$ | 1.10 | 3.12 | ..... | ..... | .2 | ..... |
| | CO | ..... | ..... | 17.8 | ..... | 6.3 | 27.5 |
| | $CO_2$ | ..... | ..... | 9.12 | ..... | 1.8 | 11.5 |
| | $CH_4$ | ..... | ..... | 4.28 | 80.5 | 31.6 | ..... |
| | Illuminants | ..... | ..... | .36 | 18.2 | 3.7 | ..... |
| | Ash | ..... | .11 | ..... | ..... | ..... | ..... |
| | Moisture | ..... | 3.1 | ..... | ..... | ..... | ..... |
| Gross Btu per unit | | 148,800 | 160,000 | 145.6 | 1151 | 599 | 95.5 |
| Net Btu per unit | | 140,000 | 154,200 | 134.3 | 1032 | 530 | 94.45 |
| Units per 1,000,000 net Btu | | 7.13 | 6.5 | 7450 | 970 | 1886 | 10,600 |
| Density, lb per unit | | 7.78 | 9.8 | .0688 | .0497 | .0298 | .07785 |
| Theoretical flame temperature F (corrected for dissociation) | | 3570 | 3700 | 3050 | 3560 | 3630 | 2700 |
| Per unit of fuel: | | | | | | | |
| Cu ft of air for perfect combustion | | 1377 | 1532 | 1.166 | 10.75 | 5.178 | .705 |
| Cu ft of dry flue gas from perfect combustion | | 1296 | 1478 | 1.81 | 9.67 | 4.639 | 1.538 |
| Cu ft of total flue gas from perfect combustion | | 1451 | 1597 | 2.02 | 11.83 | 5.885 | 1.558 |
| Total weight of flue gas, perfect combustion, lb | | 113.2 | 127.2 | .1581 | .873 | .426 | .132 |
| Density of flue gas, lb per cu ft | | .078 | .0797 | .0783 | .0737 | .0724 | .0846 |
| Ultimate $CO_2$ in flue gas, per cent | | 15.9 | 18.1 | 17.6 | 12.1 | 11.0 | 25.4 |
| Sensible heat content, Btu per unit per degree F | | 3.5 | 4.0 | .019 | .05 | .027 | .018 |

rate regulated by the rate of gasification. In practice, fuel beds may be found running 4-7 ft total depth. Automatic feed regulation, governed by gas temperature, is desirable, and gas pressure should also be controlled by automatic regulation of the steam-air blast. Gas pressure may run up to 2 in. water column, but gasification is better at lower pressures.

Gasification rates usually encountered in practice are 20-60 lb per hr per sq ft of producer grate area, and are dependent on the blast pressure, which may range 1-8 in. water column. Blast is provided by steam jet blowers or small turboblowers, the latter being preferred because the amount of steam in the blast can be regulated independently of the air blast.

The quantity of steam required is just enough to prevent clinkering in the fuel bed. With good coal, .2-.3 lb of steam per lb of coal gasified should be sufficient. Excess steam cools the fire and reduces producer efficiency. Air for gasification ranges 45-55 cu ft per lb of coal.

In normal practice, one lb of coal makes 60-70 cu ft of producer gas having a heating value of 140-150 Btu per cu ft. The gas may vary widely in analysis, but that given in Table X is typical. The heating value of the gas should represent 70-75 per cent of the heating value in the coal gasified, with another 10-12 per cent in the sensible heat in the gas.

Specific heat of a typical gas is is .014 + .000004 t Btu per cu ft per degree F. It is often taken as approximately .019.

*Natural gas* usually occurs with petroleum, and is held to be of similar origin. It is made up of the light hydrocarbons, methane, ethane, and sometimes propane, in varying proportions. A typical analysis is given in Table X. This gas has a specific gravity of .65, and a gross heating value of 1150 Btu per cu ft, For perfect combustion, one cu ft of this gas requires 10.75 cu ft of air, and produces 9.68 cu ft of dry gases and 2.15 cu ft of water vapor.

Natural gas forms a small portion of the fuels used in the open hearth. Some plants use small quantities in combination with fuel oil, and some few plants use it as the only fuel. In the latter cases, it is introduced at very low pressures, often through each side wall of the furnace ends, or sometimes at higher pressure through the end walls. Natural gas should not be preheated, as the hydrocarbons in this gas are decomposed by temperature.

*Coke oven gas* coming from the by-product plant has a specific gravity of .38-.45, and a specific heat of approximately .02 Btu per cu ft per degree F. A typical gas is shown in Table X. As in the case of natural gas, the hydrocarbons in coke oven gas will break down if the gas is preheated. In the Rose furnace, this characteristic is used to improve luminosity of the coke gas flame.

Because of its very high hydrogen content, the coke oven gas flame is quite transparent, with little luminosity. Also, the low specific gravity of the gas causes the flame to rise in the furnace and care must be used in directing the flame to avoid damaging the roof. It is generally used in combination with a liquid fuel or with blast furnace gas, in mixed gas. Some shops, however, use coke oven gas alone, either in a manner similar to that used for natural gas, or, as in the McKune system,

injecting it at the bottom of the air stream as it flows through the furnace end.

Mixed gases may contain varying proportions of coke oven and blast furnaces gases, so that the mixture may range 200-400 Btu per cu ft. With the leaner mixtures, the gas is generally highly preheated in the regenerators and handled much the same as producer gas. The richer mixtures may not be regenerated, but are handled much the same as straight coke oven gas.

*Flame characteristics*—Theoretical flame temperatures, as given in Table X, are not attained in practice, due to time lag in the burning process, radiation from the flame, incomplete combustion, and the presence of excess air. On the other hand, preheated air tends to offset these losses. Actual flame temperatures with preheated air as normally found in open hearth practice range 3200-3600 F. For good production and efficiency, flame temperatures should be as high as possible. This requires maximum preheat of air, and effective mixing of fuel and air. The use of some oxygen to support combustion increases flame temperature materially.

Flame temperature alone, however, does not tell the entire story. Rather, flame radiation, which is a combination of temperature luminosity and other characteristics, is the index to performance. Flame radiation readings may be taken by various types of equipment. One of the simplest arrangements uses a radiation tube, either portable or permanent, connected to an electronic recorder. These readings show immediately the results of changes in firing conditions and in furnace design. Thus far, most of the flame radiation work has been done by portable units, although a few permanent units have been installed recently, so that readings are constantly available.

The shape of the flame is an important factor in furnace performance. This shape, which should conform to the size and shape of the furnace, is determined in oil-fired furnaces by the area and shape of the burner nozzle and the pressure of oil and steam. In gas-fired furnaces, the flame is shaped and directed by the design of the furnace ends.

The bottom of the flame should strike the bath at about the center of the first door. It should not rise near the roof; generally, the back skewback should just be visible above the top of the flame when viewed through the wicket hole in the second door. From the third door on, the flame should be sufficiently transparent to permit seeing backwall refractories through the flame. Combustion should be completed in the furnace laboratories; secondary combustion in downtakes, slag pockets or regenerators is a waste of fuel and a source of damage to furnace structure.

## RAW MATERIALS

*Basic iron* as used in the open hearth is generally of high manganese type, falling in the following analysis range: .75-1.50 per cent silicon, 1.00-2.25 manganese, .035-.050 per cent sulphur, .15-.40 per cent phosphorus, and 3.50-4.25 per cent carbon. Individual plants will hold their own analyses within a considerably narrower range.

Iron that is too low in silicon cools the bath and slows

**TABLE XI**

**Fuel Equivalents**

| Fuel | Per million Btu, net | | |
|---|---|---|---|
| | Fuel units | Cu ft of air for combustion (at 60 F) | Cu ft of products of combustion (at 60 F) |
| Fuel oil (gal) | 7.1 | 9,800 | 10,300 |
| Tar (gal) | 6.5 | 9,950 | 10,400 |
| Producer gas (cu ft) | 7,450 | 8,700 | 15,100 |
| Natural gas (cu ft) | 970 | 10,400 | 11,500 |
| Coke oven gas (cu ft) | 1,885 | 9,800 | 11,100 |
| Blast furnace gas (cu ft) | 10,600 | 7,450 | 16,500 |

up reactions. Hence, more heat is required from the fuel. Also, the heat melts low in carbon and a poor, heavy slag is formed. Foaming may be excessive. This can be controlled by increasing the percentage of iron charged, and reducing the limestone charge. On the other hand, high silicon iron gives high temperatures and a fluid slag. The silicon deoxidizes the early slag so that the heat melts high in carbon.

Many prefer silicon toward the low side (.75-1.10 per cent for charges containing 50 per cent or less iron and lower as the iron charge increases), as each pound of this element forms two pounds of silica, which needs 5 lb of lime (10 lb of limestone) to flux it. As silicon drops, however, sulphur increases. Hence, a compromise is necessary. Sulphur may go to .04 or .05 per cent, except for deep drawing steels, which require sulphur of approximately .025 per cent.

Manganese is usually preferred at the high side of the range, as high manganese tends to reduce sulphur. Phosphorus should be toward the lower side of the range for the higher carbon steels, although this is not so essential in flush-off practice.

Silicon in iron may be reduced by treating the molten iron with roll scale in the blast furnace runner. Roll scale in amounts of 3-6 per cent may reduce the normal silicon by as much as 50 per cent. Sulphur may be reduced by treating the iron with soda ash. In some re-

**Figure 22 — These two 800 ton hot metal mixers serve the open hearth in a recent installation. Oil burners are provided to add heat as may be required.**

ports, 8 lb of soda ash per ton of iron reduced sulphur from .05 to .03 per cent.

Hot metal from the blast furnace may be used direct from the transfer ladles or it may be poured into a large mixer.

*Hot metal mixers* are generally of barrel type, constructed of steel plate and lined with silica brick, hard burned bosh brick or high silica stone. The mixer shell is usually mounted on rockers which rest on rollers, so that the mixer can be tilted to pour off the desired amount of metal. The pouring spout is usually placed away from the receiving opening. Openings may be provided with covers to conserve heat, and a gas or oil burner may be provided to add heat, although this is normally not necessary. In some cases 1½-3 million Btu per hour is put into the mixer. The life of a mixer lining is usually expressed in terms of tons put through the mixer, and may range 400-500 × the holding capacity of the vessel.

A mixer serves as a storage for hot metal between the blast furnace and the steel-making department, and by averaging out variations in chemical composition of the iron, it may permit the use of a cast that would otherwise be unacceptable.

Mixers range 200-1700 tons in holding capacity. The larger the mixer, the more effective it is in averaging out variations in iron analyses.

The temperature of iron in a mixer varies considerably, depending on the casting temperature (2550-2700 F) at the blast furnace, and the method of handling between the blast furnace and the open hearth. Metal is usually about 100 degrees F hotter where transported in a closed type of ladle than if open top ladles are used. It has also been reported that mixer metal will be 100-150 degrees F colder than if no mixer were used. Observed metal temperatures as low as 2200 F in mixers have been reported.

*Steel scrap* should be free from dirt, foreign material, or excessive rust. Alloy scrap must be carefully segregated from straight carbon scrap. Weight-space relation of various grades of scrap is approximately as follows:

| | Lb per cu ft |
|---|---|
| Short, heavy crop ends | 240-250 |
| Billet ends | 180-190 |
| Foundry gates and risers | 135 |
| Rails | 132 |
| Heavy railroad scrap | 85-90 |
| Crushed turnings | 56 |
| Compressed bundles | 50 |
| Light railroad scrap | 45 |
| Automobile scrap | 42 |

The scrap charge should be a balance between heavy and light scrap. All heavy scrap gives a slow melt-down with minimum oxidation. All light scrap is too bulky, and gives a maximum oxidation. At present, a great majority of open hearth shops are obliged to use scrap averaging 100 lb or less per cu ft.

Scrap consumption in the industry averages about 990 lb per net ton of ingots.

*Iron oxide* for open hearth use may be in the form of iron ore, roll scale or sinter. A clean lump ore, low in moisture, is most widely used, although a growing scarcity has led to increased use of sinter. Suitable ore contains 50-60 per cent iron, 4-8 per cent silica, 2-3 per cent alumina, and 5-10 per cent moisture, with traces of lime, phosphorus and sulphur. In some cases, silica now runs up to an undesirable 10-15 per cent. Sinter and mill scale are not as effective as hard ore in the elimination of carbon.

## FLUXES

*Limestone* contains 95-98 per cent calcium carbonate (53-55 per cent lime), 1-2 per cent magnesium carbonate, 1 per cent or less silica, and some oxides of aluminum and iron. Increase of silica content results in an increase in required slag volume. At about 1650 F, the carbon dioxide in the stone is driven off, leaving burnt lime to the extent of about 53 per cent of the original weight. Stones of the same chemical analysis may vary considerably in refractoriness, and therefore in the time required to properly shape up the slag. There seems to be no measure to predict the calcination rate or the rate of solution of a limestone. Limestone used in the steel industry comes principally from Indiana, Pennsylvania, Ohio, West Virginia, Michigan, and Colorado. It is usually sized in 3-8 in. pieces. In general, charge limestone should be as small as can be used without resulting in excessive blowing in the furnace.

*Burnt lime* may run 91-96 per cent calcium oxide, 1.0-1.5 per cent magnesia, and 2-3 per cent of silica, alumina, etc. The use of burnt lime instead of limestone decreases melting time and reduces oxidation of the bath. Limestone, however, may be lower in sulphur, causes more oxidation and consequently a more rapid reduction of carbon, and gives a more active heat. The available base in lime or limestone equals the sum of the percentages of lime and magnesia minus 2.5 times the percentage of silica.

*Fluorspar* analyses 65-95 per cent calcium fluoride, 3-8 per cent silica and up to as much as 30 per cent calcium and magnesium oxides and carbonates. Fluorspar is used to thin out slag. It is a concentrate of natural deposits.

*Silica sand* (which contains 98-99 per cent $SiO_2$) may be added to slags that are too basic or "limey." Some *bauxite* may also be used as a flux in special cases.

*Flux consumption* for the entire steel industry averages about 122 lb of limestone, 18.5 lb of burnt lime, 4.75 lb of fluorspar, and 5.56 lb of other fluxes per net ton of ingots.

## ADDITIONS

Various alloys and materials may be used in finishing steel. Table XII gives analyses of some of these materials.

*Manganese* is the most important of the auxiliary metals used in steel manufacture. It is applied as a deoxidizer and desulphurizer in all grades of steel, and produces a finer grain and a structure possessing greater strength and ductility. It also improves the hot working properties of steel. Manganese in steel may range from .03 per cent in irons up to 20 per cent in special steels. Standard ferro-manganese is the form generally used for the introduction of manganese into molten steel. Medium or low carbon grades may be required in low carbon steels. Silico-manganese may be used to put manganese into low carbon steels where the silicon is

## TABLE XII

### Analyses of Deoxidizing and Alloying Additions

| Material | C | Mn | P | S | Si | |
|---|---|---|---|---|---|---|
| Aluminum, ferro-, 20 per cent | .15 max | .50 | .05 | .05 | .50 | 22.5 aluminum |
| Aluminum, ferro-, 50 per cent | .15 max | .25 | .05 | .05 | .50 | 47.5 aluminum |
| Aluminum, ferro-, 90 per cent | | .50 | | | 1.00 | 91.5 aluminum, 7.0 max copper |
| Aluminum, ferro-, 95 per cent | | .50 | | | .50 | 96.5 aluminum, 2.5 max copper |
| Aluminum, ferro-, 99 per cent | | .40 | | | .20 | 99.0 aluminum |
| Aluminum flakes | | .25 | | | .25 | 99.4 aluminum |
| Aluminum-manganese-silicon | | 20.0 | | | 20.0 | 20. aluminum, 40. iron |
| Borosil | | | | | 40. | 3-4 boron |
| Ferro-boron | | | | | 3.0 | 18-25 boron, 3 aluminum |
| Manganese-boron | | 60-65 | | | 4.0 | 20-25 boron, 5 aluminum |
| Calcium metal | | | .05 | .05 | .25 | 98-99 calcium |
| Calcium-silicon | .65 | .10 | .05 | .05 | 60-65 | 28-35 calcium, 1.5 aluminum |
| Calcium-silicon-aluminum | .50 | .50 | .05 | .05 | 50-53 | 10-14 calcium, 2-10 aluminum |
| Calcium-silicon-manganese | .40 | 8-14 | .05 | .05 | 55-60 | 17-20 calcium, 2.0 aluminum |
| Ferro-chrome, high carbon | 4-5 | | | | | 66-70 chromium |
| Ferro-chrome, high carbon | 5-6 | | | | | 66-70 chromium |
| Ferro-chrome, high carbon | 6-7 | | | | | 66-70 chromium |
| Ferro-chrome, low carbon | .06 | | | | | 67-72 chromium |
| Ferro-chrome, low carbon | .10 | | | | | 67-72 chromium |
| Ferro-chrome, low carbon | .15 | | | | | 67-72 chromium |
| Ferro-chrome, low carbon | .20 | | | | | 67-72 chromium |
| Ferro-chrome, low carbon | .50 | | | | | 67-72 chromium |
| Ferro-chrome, medium carbon | 1.00 | | | | | 67-72 chromium |
| Ferro-chrome, medium carbon | 2.00 | | | | | 67-72 chromium |
| Chromium metal | .20 | | | | | 96-98 chromium |
| Chromium metal | .50 | | | | | 96-98 chromium |
| Ferro-chrome, nitrogen bearing | .10-1.0 | | | | | 60-72 chromium, .75-1.50 nitrogen |
| Cobalt metal | .20 | .15 | | .019 | .15 | 97-98.5 cobalt |
| Ferro-columbium | .3-.5 | 3.50 | .05 | .05 | 7.0 | 50-65 columbium |
| Pig copper | .1 | .4 | | | .1 | 99 copper |
| Magnesium metal | .25 | .10 | .05 | .05 | .25 | 98-99 magnesium |
| Magnesium-manganese-silicon | .50 | 22.5 | .05 | .05 | 37.5 | 32.5 magnesium |
| Ferro-manganese, standard | 6.5-6.7 | 78-82 | .3 max | | 1.0 max | |
| Ferro-manganese, low phosphorus | 5.5-6.5 | 78-82 | .1 max | | 2-5 | |
| Ferro-manganese, low iron | 7.0 | 88 | | | 1.5 max | 3.5 max iron |
| Ferro-manganese, medium carbon | 1.5 | 80-85 | | | 2.5 max | |
| Ferro-manganese, medium carbon | 1.5 | 80-85 | | | 1.5 max | |
| Ferro-manganese, medium carbon | 1.5 | 80-85 | | | 1.0 max | |
| Ferro-manganese, low carbon | .10 | 80-85 | | | 1.00 | |
| Ferro-manganese, low carbon | .15 | 80-85 | | | 1.00 | |
| Ferro-manganese, low carbon | .30 | 80-85 | | | 1.00 | |
| Ferro-manganese, low carbon | .50 | 80-85 | | | 1.00 | |
| Ferro-manganese, low carbon | .75 | 80-85 | | | 7.00 | |
| Manganese metal | .25 | 96-97 | | | 1.0 max | 2.0 max iron |
| Manganese metal | .15 | 95-96 | | | 1.5 max | 2.5 max iron |
| Manganese metal | .06 | 96-97 | | | 1.0 max | 2.0 max iron |
| Spiegeleisen | 4.0-5.5 | 19-28 | .07 | 0.25 | 1.0-3.0 | |
| Silico-spiegel | 2-4 | 25-30 | | | 5-8 | |
| Silico-manganese | 3.0 | 65-75 | | | 12-14 | |
| Silico-manganese | 2.5 | 65-75 | | | 14-18 | |
| Silico-manganese | 2.0 | 65-70 | | | 16-20 | |
| Silico-manganese | 1.0 | 65-70 | | | 20-25 | |
| Ferro-molybdenum | .10 | .10 | .05 | .05-.25 | 1.0 | 55-65 molybdenum |
| Ferro-molybdenum | 2.50 | .10 | .05 | .10-.25 | 1.50 | 55-65 molybdenum |
| Molybdenum sulphide | .10 | | | 30-37 | | 45-55 molybdenum |
| Calcium molybdate | .40 | .50 | .05-.10 | .25-.30 | 5.0 | 40-50 molybdenum, 15-30 lime |
| Molybdic oxide | | | | .25 max | | 53-60 molybdenum, 18 max silica |
| Nickel | Trace | .05 | | | | 98.5-99.5 nickel |
| Ferro-phosphorus | .3-1.0 | .2-.5 | 18-25 | .05 | .1-1.0 | |
| Ferro-selenium | 1.50 | .25 | .30 | 1.0 | .75-1.25 | 50-60 selenium |
| Ferro-silicon, 15 per cent | .5-1.0 | | .05 | .04 | 14-20 | 74-84 iron |
| Ferro-silicon, 50 per cent | .5-1.0 | | | | 42-52 | 45-55 iron |
| Ferro-silicon, 75 per cent | | | | | 70-82 | 17-29 iron |
| Ferro-silicon, 85 per cent | | | | | 82-88 | 10-16 iron |
| Ferro-silicon, 90 per cent | | | | | 88-90 | 7-9 iron |
| Ferro-silicon, 90 per cent special | | | | | 90-96 | 3-7 iron |
| Refined silicon | | | | | | 96-97 silicon, 1-2 iron |
| Ferro-manganese-silicon | .60 | 20-25 | | | 47-54 | 25-30 iron |
| Iron sulphide | .50 | .20 | .025 | 25-36 | .25 | |
| Iron sulphide, synthetic | .50 | .20 | .025 | 40-50 | .25 | |
| Sulphur crystals | | | | 99.9 | | |
| Ferro-titanium, low carbon | .10 | 1.0 | .10 | .05 | 2.50 | 20-30 titanium, 3.5 aluminum |
| Ferro-titanium, high carbon | 3.5-4.5 | .35 | .10 | .10 | 3.25 | 15-22 titanium, 2.0 aluminum |
| Ferro-titanium, high aluminum | .20 | 1.25 | .10 | .05 | 1.0-4.0 | 20-30 titanium, 5-8 aluminum |
| Ferro-titanium, high sulphur | .10 | | | 10. max | | 40 min titanium, 3. aluminum |
| Titanium-zirconium-boron | | 8.0 | | | | 20 titanium, 4 zirconium, 13 aluminum, .5 boron |
| Ferro-tungsten | .2-2.0 | .60 | .03 | .07 | 1.0 | 76-82 tungsten |
| Ferro-vanadium | .5 max | | | | 2.0 max | 35-40 vanadium |
| Ferro-vanadium, special | 1.0 max | | | | 4.0 max | 35-40 vanadium |
| Ferro-vanadium, high speed | .2 max | | .06 | | 1.5 max | 35-40 vanadium |
| Ferro-silicon-zirconium | .2 max | | | | 39-43 | 12-15 zirconium |
| Silicon-zirconium | .5 max | | | | 47-52 | 35-40 zirconium, 6-10 iron |

not objectionable. It is often used to block a heat. Spiegeleisen is generally used to cause a reboil in the bath before making final additions.

*Silicon* is advantageous largely due to its activity in eliminating injurious oxides and gases from steel. The 50 per cent grade of ferro-silicon is most extensively used for deoxidizing purposes in the production of semi-killed and killed steels. Higher silicon contents are used as ladle additions in the production of high silicon steels, and for slag treatment. The 15 or 25 per cent ferro-silicon is used in the furnace to block a heat, and as a deoxidizer before adding expensive alloys.

*Chromium* exerts a powerful influence in the properties of steel subjected to heat treatment. It greatly increases hardenability and resistance to shock, and it imparts high tensile strength with great ductility. It is most advantageously added to steel in the form of ferro-chrome with varying carbon content. High carbon ferro-chromium is generally used as a furnace addition for the usual open hearth products. Briquets of ferro-chromium mixed with chemical agents to provide exothermic action permit ladle additions of chromium.

*Nickel* increases strength without loss of ductility, and tends to retard grain growth. It increases the resistance of steel to impact, and aids in carburizing. It is used in metallic form as a furnace addition.

*Vanadium* is a strong deoxidizer, but is used only for its alloying qualities. It imparts a fine grain size, improves tensile strength without loss of ductility, and increases elastic limit, yield point, and impact strength. Ferro-vanadium is used as a ladle addition.

*Molybdenum* imparts toughness and contributes materially to the deep hardening qualities of steel. When present in adequate amounts, it induces the phenomenon of secondary hardness, and virtually eliminates temper brittleness, thus increasing toughness for a given hardness. For steels containing less than one per cent molybdenum, molybdic oxide or calcium molybdate is used as a furnace addition. Ferro-molybdenum is added to the bath for steels of higher percentages of molybdenum.

*Zirconium* has three definite actions—it is strongly deoxidizing, it combines with nitrogen dissolved in the steel, and it reacts with sulphur. Its use promotes freedom from inclusions, uniformity of grain, excellent hot-working properties, and good ductility. The alloy is usually added in the ladle.

*Tungsten* is used in specialty items, such as steels for tools, dies, magnets, etc. It is particularly effective in imparting strength and hardness to alloys at high temperatures. Ferro-tungsten is added to the bath.

*Titanium* is used principally as a deoxidizer and scavenger, leaving only barely appreciable amounts of titanium in the steel. It may be used in high carbon killed steels as a final deoxidizer to prevent occurrence of segregation and of objectionable inclusions, or in low carbon rimming steels in combination with aluminum or other deoxidizers.

*Boron*, in extremely small percentages, increases the hardenability of steel. It may be added as ferro-boron, or through various mixtures containing high percentages of aluminum, titanium, vanadium, zirconium, manganese, or silicon to protect the boron from oxidation.

*Sulphur* may be added to steel in quantities up to .30 per cent to improve machinability in fast cutting operations.

*Phosphorus* may be used in quantities up to .13 per cent in low alloy, high strength steels to gain strength and corrosion resistance.

*Aluminum* is used principally for grain size control, tending to produce a fine-grained steel. It also has excellent deoxidizing properties, and is used as a ladle or mold additions for this purpose.

*Carbon* is introduced into the open hearth in the iron charge and in the various ferro-alloys added. If still more carbon is needed, it may be added in the form of graphite, coke or anthracite coal. Coal is generally used as a ladle addition in open hearth practice.

*Consumptions* of the various alloying materials in the steelmaking process, based on 1946 consumptions, are approximately as follows:

| | Lb per net ton of ingots |
|---|---|
| Manganese | 11-13 |
| Silicon | 3-4 |
| Chromium | 2.45 |
| Nickel | 1.02 |
| Vanadium | .019 |
| Molybdenum | .16 |
| Zirconium | .027 |
| Tungsten | .064 |
| Titanium | .055 |
| Cobalt | .011 |
| Columbium | .005 |
| Aluminum | .55-.60 |

## TYPE OF CHARGES

Open hearth charges may be of five fundamental types:

*Hot metal-scrap heats* comprise the source of most of the steel production in the United States. These charges may consist of 30-75 per cent of hot metal, and the remainder of scrap. When the iron charge exceeds 45 per cent, ore must also be charged or fed into the bath. When the iron charge exceeds 55 per cent (or perhaps 65 per cent with low silicon iron), slag flushing practice is necessary. This last type of charge is termed an "ore heat" or "high hot-metal heat." A very appreciable iron yield is gained from the reduction of ore in high hot-metal heats, but the overall yield may be less than on non-flush practice.

*All-hot-metal heats* are the result of carrying high hot metal practice to the ultimate, using ore but no scrap. This practice is not used commercially in the United States.

*Pig iron-scrap heats* are widely used by non-integrated plants having no blast furnace to provide hot metal. This type of charge usually consists of 15-40 per cent cold pig iron, with the balance scrap. Flush practice is not usual with all-cold charges.

*All-scrap heats* are used only in a few small non-integrated plants where pig iron is not available. Such charges may consist of 100 per cent steel scrap with as much as one per cent of coke or other carbonaceous material, or they may be made up of a mixture of steel and iron scrap so that no additional carbon is needed. Coke added to scrap charges is approximately 70 per cent efficient as a carbonizer.

*Blown metal heats* can be made only in plants having bessemer converters to supply the blown metal, and having enough blast furnace capacity to supply all or

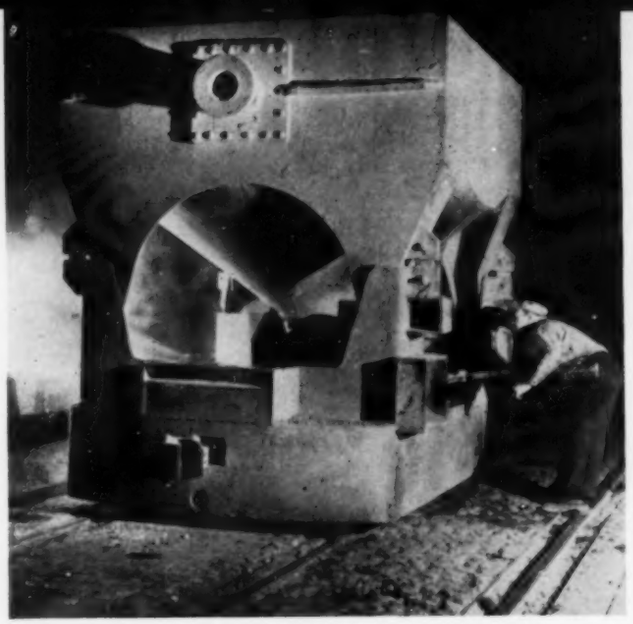


**Figure 23 — Dolomite machines are used in many plants in repairing bottoms and banks between heats, and eliminate much of the manual shoveling otherwise entailed.**

**Figure 24 — Modern charging machines are usually of 10–15 ton capacity and have bridge speeds of 400–450 fpm.**

almost all of the entire metallic charge. These charges may consist of 70-95 per cent of full blown metal and 30-5 per cent of raw iron, as in the conventional duplex process, or they may be composed of 70-80 per cent of partially blown metal (1-1½ per cent carbon) and 30-20 per cent scrap.

The type of charge used in any particular plant is actually a matter of available supplies and the economics thereof.

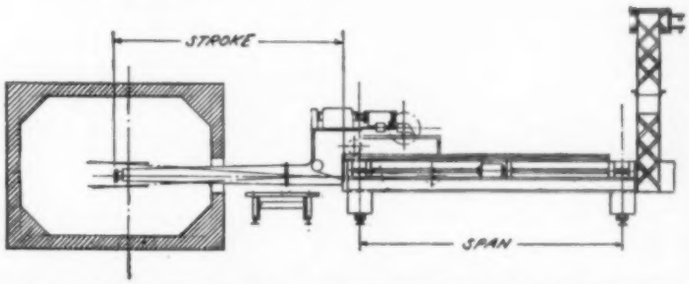
## CHARGING AND MELTING

Before a heat is charged, the bottom and banks of the furnace are inspected. All pockets and holes must be emptied of liquid steel and filled with dolomite or magnesite. The banks are resurfaced with raw or burned dolomite, which is shoveled manually or sprayed by a dolomite machine and dolomite is lightly strewn over the bottom. The tap hole is dried out with dolomite, which is then removed, and the tap hole is then closed with dolomite and a 4-6 in. plug of loam or fire clay. The inside of the hole is then faced off with magnesite or burned dolomite.

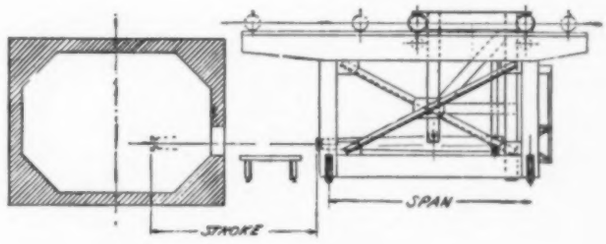
Over the years, charging has become more and more of a bottleneck in the open hearth process, and charging time offers a fertile field in which to look for opportunities to speed up production.

Charging machines, which handle all cold materials into the furnace, are almost universally in-and-out, floor type units, with an angular, elevating, revolving peel. The peel is equipped with a lock rod which prevents the charging box from disengaging as it is revolved in the furnace to deposit its contents in the furnace. As furnaces became larger, it became necessary to use larger, faster charging machines. In the latest plants, these machines are of 10-15 tons capacity, and have a span of about 25 ft and a stroke of 20 ft. These machines may be either of high or low type. The high type permits the girders to project over the charging buggy tracks, and provides maximum travel of trolley and peel

**Figure 25 — The sketches below show general characteristics of charging machines of both the low type (top) and high type (bottom).**




| CAPACITY IN TONS | SPAN C TO C OF RAILS | STROKE OF RAM | TOTAL WT. OF CHARGER | DRAW BAR PULL BASED ON 20% FRICTION | MAX. WHEEL LOAD WITH FULLY LOADED BOX IN EXTREME POSITION IN FURNACE (4 WHEELS ON BRIDGE) |
|---|---|---|---|---|---|
| 3 | 22'-0" | 18'-0" | 125,000 | 25,000 | 60,000 |
| 5 | 24'-0" | 20'-0" | 150,000 | 30,000 | 72,000 |
| 7½ | 25'-0" | 20'-0" | 175,000 | 35,000 | 86,000 |
| 10 | 26'-0" | 20'-0" | 200,000 | 40,000 | 100,000 |
| 12 | 27'-0" | 21'-0" | 220,000 | 44,000 | 110,000 |
| 15 | 27'-0" | 21'-0" | 240,000 | 48,000 | 120,000 |




| CAPACITY IN TONS | SPAN C TO C OF RAILS | STROKE OF RAM | TOTAL WT OF CHARGER | DRAW BAR PULL BASED ON 20% FRICTION | MAX. WHEEL LOAD WITH FULLY LOADED BOX IN EXTREME POSITION IN FURNACE (4 WHEELS ON BRIDGE) |
|---|---|---|---|---|---|
| 1 | 11'-0" | 12'-0" | 50,000 | 10,000 | 25,000 |
| 2 | 12'-0" | 14'-0" | 65,000 | 13,000 | 33,000 |
| 3 | 13'-0" | 16'-0" | 85,000 | 17,000 | 43,000 |
| 5 | 14'-6" | 17'-0" | 115,000 | 23,000 | 59,000 |
| 7½ | 14'-6" | 17'-0" | 130,000 | 26,000 | 69,000 |
| 10 | 15'-0" | 17'-6" | 140,000 | 28,000 | 74,000 |

**Figure 26 — This string of charging boxes is filled with the miscellaneous type of scrap that is all too prevalent at the present time.**

for a given bridge span. It is particularly adaptable where space is restricted. The low type, although it requires greater space, is preferred by operators because of its rigidity of construction.

Charging boxes are generally made of cast steel, although many boxes in use are fabricated from steel plate with heavy plate or cast steel ends. They range 20-55 cu ft in capacity, the tendency being to make them as large as the size of the furnace door and the height of the furnace roof will permit, so that a minimum number will be required to charge a heat.

Boxes can be charged into the furnace at a rate of 40-60 boxes per hour, and occasionally up to 75 or 80. The capacities of boxes are approximately as given in Table XIII. It is at once apparent that light scrap entails the charging of many boxes, with consequent lengthening of charging time.

Factors that will help to speed up charging may be summarized as follows:

1. Adequate size of stockyard.
2. High speed stock cranes, with large, high capacity magnets for speedy handling.
3. Facilities for increasing density of light scrap and for cutting up large pieces.
4. Large scrap boxes.

**TABLE XIII**

**Holding Capacity of Charging Boxes**

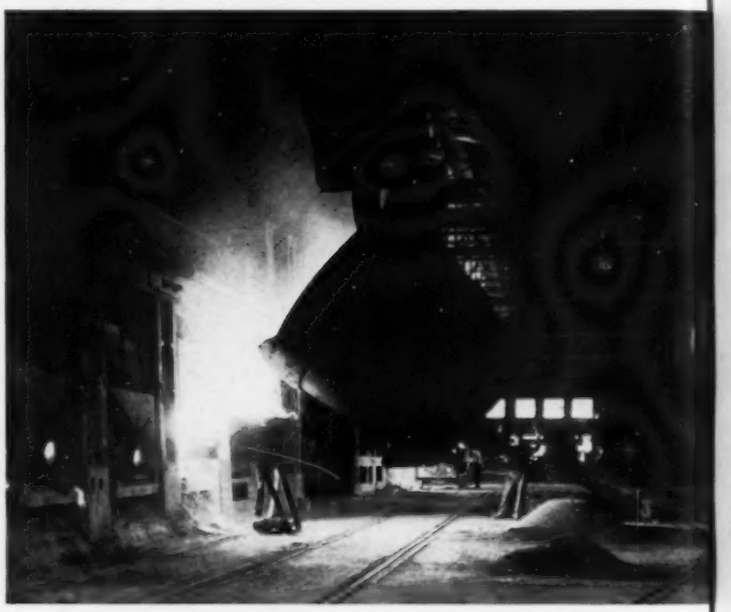
| Size of scrap box, cu ft | Capacity of scrap box, lb | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Short, heavy crop ends | Billet ends | Foundry gates and risers | Rails | Heavy railroad scrap | Crushed turnings | Compressed bundles | Light railroad scrap | Automobile scrap |
| 20 | 4,900 | 3,700 | 2700 | 2640 | 1750 | 1120 | 1000 | 900 | 840 |
| 25 | 6,125 | 4,625 | 3375 | 3300 | 2190 | 1400 | 1250 | 1125 | 1050 |
| 30 | 7,350 | 5,550 | 4050 | 3960 | 2625 | 1680 | 1500 | 1350 | 1260 |
| 40 | 9,800 | 7,400 | 5400 | 5280 | 3500 | 2240 | 2000 | 1800 | 1680 |
| 50 | 12,250 | 9,250 | 6750 | 6600 | 4375 | 2800 | 2500 | 2250 | 2100 |
| 60 | 14,700 | 11,100 | 8100 | 7900 | 5250 | 3360 | 3000 | 2700 | 2520 |

5. Larger open hearth doors to accommodate the larger boxes.
6. Charging machines of sufficient speed and capacity.

Charging boxes are transported on buggies that accommodate three to six each. Modern installations use standard gage buggies, although there are still many plants using narrow gage.

In charging the furnace for scrap-hot metal heats, some fairly light scrap is usually strewn over the furnace bottom (about one buggy in each door), and the limestone then charged. The bulk of the scrap is then added, and melting begun. With light, bulky scrap, it may be necessary to melt down several times before all of the scrap can be charged into the furnace.

**Figure 27 — Hot metal is poured from the ladle into the furnace through a portable runner placed in front of the middle door. Hot metal additions must be properly timed.**



If ore is required in the charge, it is charged immediately on top of the limestone so that the stone is well covered. This is particularly essential with high iron charges that require flushing slag; otherwise, the lime will float up into the flush slag.

After the scrap is partially melted, the iron is added. Hot metal additions must be properly timed, the timing becoming more critical as the percentage of iron in the charge increases. All of the scrap should be as high in temperature as the metal to be added, and should be running freely. This may occur 3½-6 hr after the start of charging. If hot metal additions are too late, the scrap becomes highly oxidized, the heat will melt low in carbon, and excessive foaming may result. If hot metal is added too soon, it will be chilled by the cold scrap, and the bath will be inactive. When the reactions do begin, foaming may occur.

When cold iron is used, the timing of its charging is not very critical, as the reactions go on while it melts. Cold iron is usually added as soon as the scrap has partially melted and absorbed most of any added carbonizers.

In charging an all-scrap heat, the furnace bottom is

usually covered with a light layer of scrap, and the limestone then charged. If some burnt lime is also used it may be put on top of the limestone or on top of a light layer of scrap covering the limestone. The carbonaceous material is charged on top of another layer of scrap, and is followed by the rest of the scrap.

For blown metal charges, limestone is charged on the furnace bottom. In conventional duplexing, blown metal is then added, followed by the raw hot metal from the blast furnace. These two metals are generally proportioned so that the bath averages a carbon content of about ½ per cent above the desired tapping content, and the carbon is then reduced by the addition of ore. When using partially blown metal (synthetic scrap), the limestone is charged first, followed by the cold scrap and then by the molten metal.

In the duplex process, the metal is highly oxidized, and the addition of raw iron causes a boil. After the boil, carbon elimination proceeds as in scrap practice, and the heat is handled in a similar manner.

Typical analyses of the iron and metal in the duplex process (85 per cent full blown metal—15 per cent raw iron) are approximately as follows:

| | Iron | Full blown metal | Steel at tap | Ladle analysis after additions |
|---|---|---|---|---|
| C | 4.25 | .10 | .07 | .08 |
| Mn | .45 | .05 | .11 | .40 |
| P | .175 | .190 | .020 | .020 |
| S | .035 | .040 | .025 | .025 |
| Si | 1.30 | .03 | .01 | .01 |

When partially blown iron is used, typical analyses are as follows:

| | Iron | Partially blown metal | Steel at tap | Ladle analysis after additions |
|---|---|---|---|---|
| C | 4.00-4.40 | 1.00-1.25 | .10 -.20 | .15 -.25 |
| Mn | 1.00-1.25 | .15 -.25 | .10 -.12 | .30 -.40 |
| P | .30- .34 | .33 -.37 | .015-.030 | .015-.030 |
| S | .035 | .040 | .02 -.03 | .02 -.03 |
| Si | 1.00-1.20 | .02 -.05 | .01 -.02 | .01 -.02 |

Because blown metal is very low in silicon, slag volume in blown metal processes is usually much lower than with regular scrap-hot metal charges. Limestone charges are reported as low as 3½ per cent, and with rather high phosphorus charges, only 5 per cent.

During the melting period, a short, sharp flame is generally preferred. Fuel input can be high, as the relatively cold charge holds furnace temperature below damage levels. As the charge melts, oxidation occurs to a degree depending on the type of scrap and the time required for melting. These oxides react with the metalloids of the hot metal addition, the severity depending on the degree of oxidation. A slag, heavy in iron, manganese and silica, is formed. Reactions between the oxides and the carbon in the iron form gas which rises up through the slag, raising its level in the furnace. With high hot-metal charges (above 55 per cent), this reaction is strong enough to keep the slag level above the cinder notch, resulting in a slag run-off or flush that may last about one hour. Charges containing less than 55 per cent iron (or less than 65 per cent iron if silica in the iron is under .70 per cent) will not give, and do not require, a flush.

As the bath is further heated, the limestone of the charge is calcined, giving off carbon dioxide and starting the lime boil, which may last 1-2½ hr. Evolution of the carbon dioxide agitates the bath, and the lime rises to the surface and gradually dissolves in the slag. If burnt lime is used instead of limestone, it rises to the surface without a boil. The lime boil is usually finished 3-5 hr after charging is finished.

The addition of fluorspar thins the slag, and helps to put the lime into solution. As lime goes into solution, silica is neutralized, forming di-calcium silicate. Next, as more lime goes into solution, it combines with phosphorus to form tri-calcium phosphate. Still more lime goes to form di-calcium ferrite. These three successive steps in the combination of lime with silica, phosphorus pentoxide and iron oxides are important in the open hearth process, and will be subsequently discussed at greater length.

## THE PROCESS

Open hearth reactions are essentially oxidizing, produced by the action of iron oxide which enters the charge from the following sources:

1. Rust present on the scrap charged.
2. Oxidation of scrap by moisture in the charge and by furnace gases during the melting period.
3. Oxidation of FeO in slag to $Fe_2O_3$, which is then reduced at the slag-metal surface to FeO.
4. Decomposition of limestone frees $CO_2$, which oxidizes iron in the bath.
5. Direct charging of iron ore or mill scale.
6. Oxidation by direct introduction of oxygen into the bath.

Oxidation of the elements in the bath proceeds approximately in the following order:

*Silicon* is oxidized by the reaction:

$$Si + 2\ FeO = SiO_2 + 2\ Fe$$

The reaction is rapid and practically complete. The average open hearth heat contains less than .01 per cent silicon at tap.

*Manganese* oxidizes slightly less rapidly than silicon, with the following reaction:

$$Mn + FeO = MnO + Fe$$

Larger amounts of manganese are retained in the metal bath than in the case of silicon. Residuals run .08-.25 per cent. The higher manganese residuals are promoted by low oxygen content of the bath, by heavy slags with low oxygen content, and by high temperatures.

*Phosphorus* is oxidized by the reaction:

$$2\ P + 5\ FeO = P_2O_5 + 5\ Fe$$

If slag conditions are not suitable for retaining phosphorus, phosphorus reverts rapidly from slag to bath. With basic slags having a lime-silica ratio of about 3, the phosphorus residual of an average heat will be .010-.015 per cent.

*Carbon* is not oxidized to any great extent until silicon and manganese are fairly well eliminated. Its oxidation comes through the reaction:

$$C + FeO = CO + Fe$$

The elimination of carbon can be fairly rapid down to about .05 per cent. Heavy ore additions can lower carbon to .015-.020 per cent.

*Sulphur* is probably oxidized only during the melting of high sulphur scrap. This reaction would be:

$$S + O_2 = SO_2$$

The elimination of sulphur from the bath takes place through the reaction:

$$2S + 2CaO = 2CaS + O_2$$

Some sulphur is also at times held in the slag as $CaSO_4$.

Sulphur removal is favored by high temperatures, by slags low in iron oxide, high in basicity and of good fluidity, and by high residual manganese. Ordinarily, the slag basicity required for sulphur removal is greater than that required for phosphorus removal, and for better control of sulphur, it is advantageous to have this higher basicity in the earlier stages of the heat.

*Iron* is oxidized during the melting period as follows:

$$2\,Fe + O_2 = 2\,FeO$$
$$Fe + CO_2 = FeO + CO$$
$$Fe + H_2O = FeO + H_2$$

After the heat is under cover, the iron continues to be oxidized by the transfer of oxygen through the slag by iron oxides:

$$Fe_2O_3 + Fe = 3\,FeO$$
$$4FeO + O_2 = 2Fe_2O_3$$

The refining period nominally begins after the heat is melted, although some phases of it may begin even before that point. During the refining period, phosphorus and sulphur in the bath should be reduced to points safely below the maximum specified contents, the slag properly shaped up, carbon reduced, bath temperature brought to the proper point, and the carbon and oxygen contents brought to proper levels for the grade of steel to be produced.

A good slag will have different characteristics in accordance with the type of steel, as discussed subsequently in this article. Slag may be thinned out by additions of fluorspar or mill scale, and its chemical composition may be varied by adding burnt lime, limestone, iron oxide or silica sand.

Generally, operators prefer that the furnace charge melts with a carbon content about .5 per cent higher than the tapping requirement. As a rough estimate, it may be said that charges usually melt with ⅓-½ of the carbon content of the charge, if a normal amount of silicon is present. The melt carbons, however, may vary widely on either side of the desired point. Consequently, ore or pig iron may be required to lower or raise the carbon. Without such additions, carbon normally drops at a rate of .15-.50 per cent per hr during the refining period. This rate depends on many variables, but for a given furnace, fuel and charge, it is remarkably uniform from heat to heat. Rapid carbon drop is promoted by shallow baths, fluid slags, low slag volumes, high iron charges, and liquid fuels. Ore additions to reduce carbon average about five times the weight of the carbon to be removed, although a given ore addition will remove more carbon from a high carbon bath than from a low carbon bath.

Two basic methods are used in getting the right carbon content in the steel. Heats may be worked down to a comparatively low carbon and then recarburized in the furnace or in the ladle; or the carbon may be worked down to or slightly below the desired range, requiring only minor correction. Rapid methods of carbon determination have tended to promote the latter method.

**Figure 28 — The charts on the opposite page show the analyses of the metal bath and of the slag during the progress of a scrap-hot metal heat. The various additions are noted, and the behavior of the various elements may be traced.**

As the heat progresses, samples of the bath are taken for chemical analysis. Rapid carbon determinations are also available from various types of equipment now available, and these devices are receiving wide acceptance.

In addition to these determinations, various approximations are made by the furnace personnel.

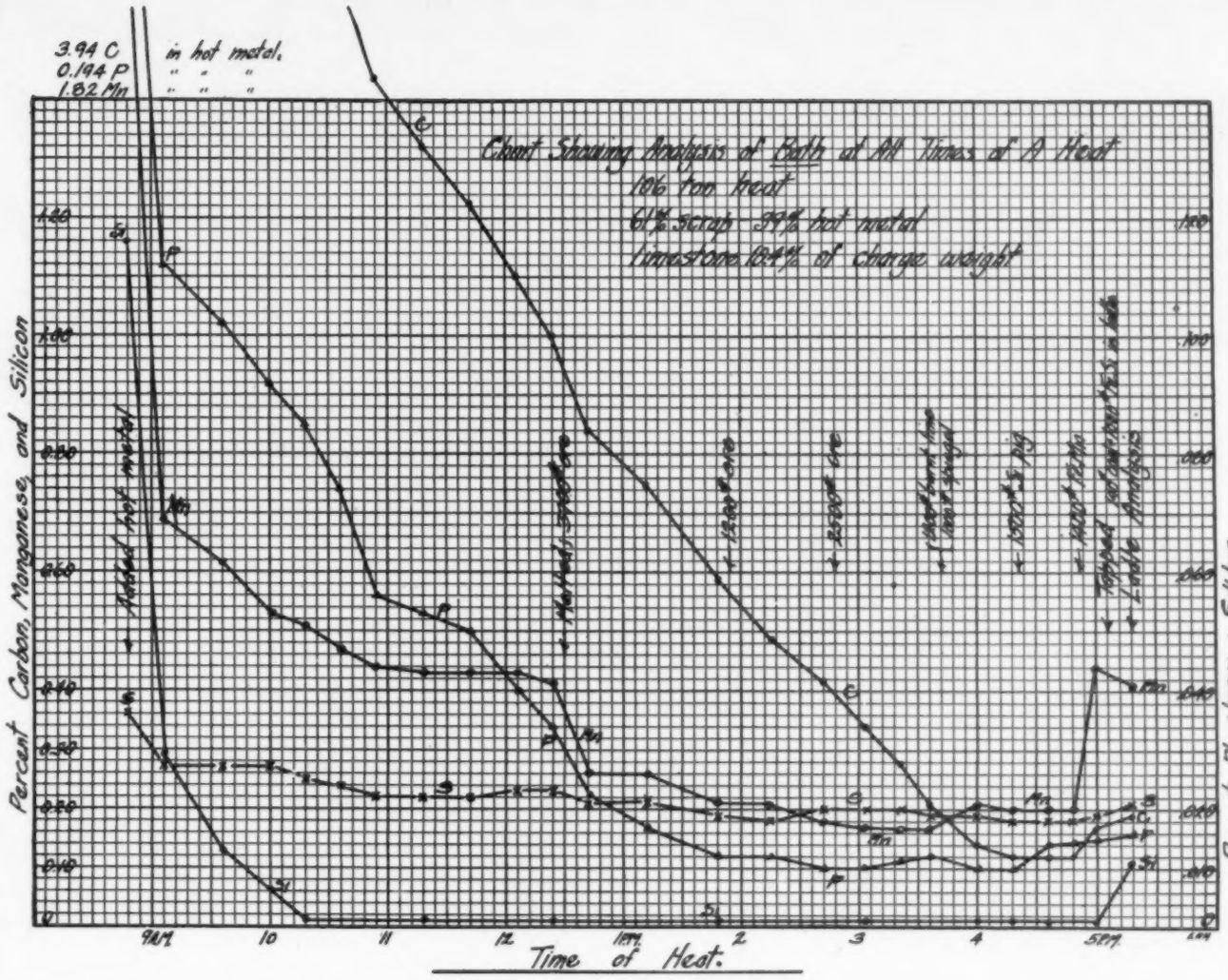
Carbon fracture tests are made by taking a spoonful of steel (covered with slag) from the furnace and pouring it into a mold approximately 1 in. x 2 in. x 4 in. The sample is cooled in water and fractured. The experienced observer can, from the appearance of the grain and the blowholes, estimate the carbon content. This determination can be quite close with carbon under .30 per cent, but becomes more difficult as the carbon increases. Above .40 per cent carbon, it is difficult to estimate within 10 points of the actual content.

Several methods of measuring molten steel temperature have been used with varying success. Various types of thermocouples have been tried, including tungsten-molybdenum, tungsten-graphite, carbon-silicon carbide, and platinum-platinum rhodium. This last type, protected at the end by only a thin quartz tube, seems to be favored, as a satisfactory reading can be obtained in 15-30 sec.

Radiation methods used to measure molten steel temperature include optical pyrometers, two-color pyrometers, photo-electric pyrometers, and total radiation pyrometers. The preferred method seems to be the use of a steel tube, open at the one end which is immersed in the steel bath. Compressed air is blown through the tube to keep molten steed out of the tube, while an optical pyrometer, photo-electric cell or total radiation pick-up is sighted through the tube end on to the molten steel.

Various practical methods of estimating bath temperature are in use. Perhaps the most prevalent is the rod test, in which a steel stirring rod of given carbon content is moved slowly in the bath. The shape of the end of the rod, after one or two minutes immersion, is a relative indication of temperature. The cut-off may range from concave with nicks in the slag line for a very hot heat, or a square cut-off for a hot heat, through pointed cut-offs for medium or slightly cold heats, to a skulled end for a very cold heat.

Temperatures may also be judged by observation of metal poured over the lip of a spoon, checking solidification in a chill mold, and observing the skull on the spoon, or by checking the time for a spoonful of metal to "skin over." Fluidity may also be judged from the way metal scatters when poured slowly on a flat surface.


3.94 C in hot metal.
0.194 P " " "
1.82 Mn " " "
Chart Showing Analysis of Bath at All Times of A Heat
186 Ton Heat
61% Scrap 39% hot metal
Limestone 10.4% of charge weight
Percent Carbon, Manganese, and Silicon
Percent Phosphorus & Sulphur
Time of Heat.

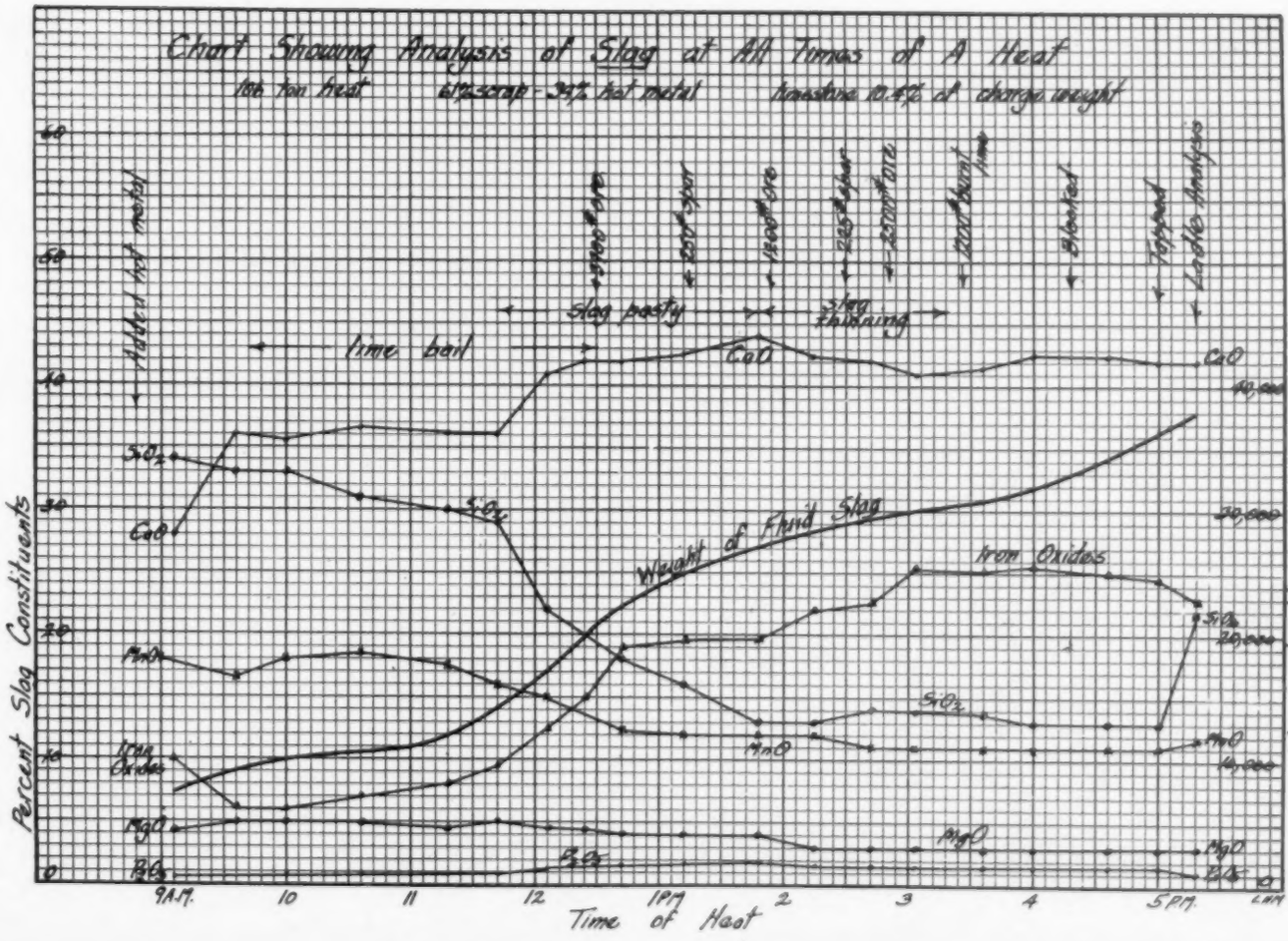


Chart Showing Analysis of Slag at All Times of A Heat
186 Ton Heat 61% scrap - 39% hot metal limestone 10.4% of charge weight
Slag pasty
Slag thinning
lime boil
CaO
SiO2
MnO
MgO
Al2O3
Iron Oxides
Weight of Fluid Slag
from Oxides
Percent Slag Constituents
Slag Weight (lbs.)
Time of Heat

## WORKING AND FINISHING THE HEAT

Steel produced in the open hearth falls into one of three broad classes: killed, semi-killed, and rimmed (including capped), all depending on the degree of oxidation or deoxidation of the steel, and in some cases, one type may merge into the next.

*Killed steel* is generally used when a dense, homogeneous structure is required. Alloy steels, and forging and carburizing grades are made by this practice. The carbon content may range .05-1.50 per cent.

For fully killed steel, it is usually desirable to bring the oxygen content of the bath as low as possible. This means that the slag should be as mildly oxidizing as possible, and the tapping carbon should be as high as the specified analysis will permit. This slag condition can be obtained by first using a lime-silica ratio of about 2.1, and then increasing the lime rapidly during the last hour of the heat to a ratio of 2.4-2.6, or higher if necessary.

Many plants employ a reboil in working the heat. Spiegel or pig iron is generally used, in amounts ranging ½-1 per cent for the former and 2-4 per cent for the latter. The addition lowers the rate of carbon drop and allows time for adjustments of slag and temperature. It is also beneficial to steel cleanliness. The reboil may last for ½-1 hr.

When the bath reaches the desired carbon content, the heat is blocked to reduce its oxygen content to a low value. Materials usually used for blocking are 15, 25 or 50 per cent ferro-silicon, silico-manganese or spiegel. This addition may put .07-.22 per cent silicon into the bath, the amount depending on the degree of oxidation of bath and slag, and on the length of block desired. To maintain a satisfactory block, silicon remaining in the steel at tap should be .02-.06 per cent. After the heat is blocked, reaction between steel and slag stops for a period of 20-35 minutes, allowing time for adjustments of chemical compositions. Alloy additions must be made and the heat tapped within 20-45 minutes of the block. Burnt lime additions may be advisable 15-30 minutes before the block, since, to prevent reversion of phosphorus, the lime-silica ratio of the slag should be 2.8-3.0, depending on the length of block.

Additions as dictated by test results may then be made to bring the steel to the specified chemical composition. These additions are variously made in either furnace or ladle. Manganese may be added in the furnace or in the ladle, or divided both ways. Manganese recovery is higher from ladle additions, but steel cleanliness may benefit from furnace additions. Many plants add most of the manganese and other alloys to the furnace, keeping only those materials which oxidize rapidly (aluminum, silicon, vanadium, etc.) as ladle additions. Furnace time may be saved by making all additions in the ladle, but it is widely felt that this practice does not give close control of composition, particularly when the additions are large. Also, the chilling effect of large additions in the ladle must be considered. On the other hand, furnace additions must be able to penetrate the slag and enter the bath, and they may cause some phosphorus reversion.

The removal of iron oxide by deoxidizers forms nonmetallic inclusions in the steel, which should be eliminated insofar as possible. Elimination depends on particle size and density, fluidity of the steel, and the distance the particle must rise through the steel. Inclusions high in silica do not seem to be eliminated readily. A manganese-silicon alloy has proven effective for deoxidization, and is said to produce cleaner steel. The manganese-silicon ratio may vary from 4-7, the higher values being used for the high carbon steels and for highly oxidized baths and slags. Aluminum is also widely used, particularly as a mold addition, to complete deoxidization and to regulate grain size.

*Rimmed steel* is used principally for strips, sheets, plate, skelp, rod and wire. Steel of this type, properly made, has a minimum of pipe, and has a good surface, but is subject to blowholes and segregation. Carbon content must generally be below .30 per cent, and only the slow-oxidizing alloys (copper, nickel, molybdenum, etc.) can be used.

Rimmed steel must contain sufficient oxygen at tap to produce the desired rimming action in the molds. Hence, the slag must be of oxidizing nature. Sufficient oxidation is almost too readily attained for low carbon heats. Above .12 or .15 per cent carbon, efforts may be necessary to increase oxidation in order to get good rimming action, and above .25 or .35 per cent it is virtually impossible to reach a degree of oxidation that will give good rimming action. Generally, the slag must be above 2.4 lime-silica ratio. Ore additions should be made so that there is sufficient time for them to work out before the heat is tapped.

Usually, the carbon content of the bath is reduced below the final value desired (3-10 points below for carbons of .10-.25 per cent; more for higher carbons), and the steel then recarburized in the ladle. Bath and slag conditions should be so balanced that the rate of carbon drop is steady and not excessive.

As in killed steel practice, manganese may be added in the furnace or in the ladle, or both ways. However, due to the highly oxidized state of the bath, manganese recovery from furnace additions is quite low, and ladle additions are more widely used. Final manganese content usually may not exceed .40 per cent without ad-

**TABLE XIV**

**Efficiencies of Alloying Elements**

| Addition | Element sought | Per cent efficiency when added in | |
|---|---|---|---|
| | | Furnace | Ladle |
| Ferro-manganese | Mn | 40-80 | 60-90 |
| Ferro-silicon (15%) | Si | 20-40 | Never |
| Ferro-silicon (other) | Si | Never | 65-85 |
| Ferro-chromium | Cr | 55-75 | ..... |
| Ferro-vanadium | V | Never | 50-80 |
| Ferro-phosphorus | P | Never | 55-75 |
| Ferro-molybdenum | Mo | 90-98 | Never |
| Molybdenum salts | Mo | 90-98 | Never |
| Spiegel | Mn | 50-80 | Never |
| Silico-manganese | Si | 20-40 | Never |
| | Mn | 50-80 | Never |
| Nickel | Ni | 96-99 | Never |
| Copper | Cu | 96-99 | Never |
| Stick sulphur | S | Never | 50-70 |
| Anthracite coal | C | Never | 40-90 |
| Pig iron | C | 95 | Never |

**TABLE XV**

**Weights of Oxides Reduced and Metal Produced by One Pound of Reducing Element**

| Metallic oxides | From 1 lb of pure carbon | | From 1 lb of pure silicon | | From 1 lb of pure aluminum | |
|---|---|---|---|---|---|---|
| | Lb of oxide reduced | Lb of metal produced | Lb of oxide reduced | Lb of metal produced | Lb of oxide reduced | Lb of metal produced |
| CuO | 6.6309 | 5.2979 | ..... | ..... | ..... | ..... |
| $Cu_2O$ | 11.9283 | 10.5952 | ..... | ..... | ..... | ..... |
| $Cr_2O_3$ | 4.2223 | 2.8891 | 3.6118 | 2.4714 | 2.8183 | 1.9285 |
| FeO | 5.9867 | 4.5533 | 5.1206 | 3.9802 | 3.9946 | 3.1057 |
| $Fe_2O_3$ | 4.4356 | 3.1025 | 3.7938 | 2.6534 | 2.9605 | 2.0705 |
| $Fe_3O_4$ | 4.8233 | 3.4900 | 4.1254 | 2.9851 | 3.2193 | 2.3293 |
| MnO | 5.9103 | 4.5576 | 5.0555 | 4.9289 | 3.9436 | 3.0540 |
| $MnO_2$ | 3.6221 | 2.2896 | 3.0380 | 1.9789 | 2.4174 | 1.5442 |
| $MoO_3$ | 4.0000 | 2.6667 | 3.4213 | 2.2808 | 2.6696 | 1.7798 |
| NiO | 6.2242 | 4.8906 | 5.3236 | 4.1830 | 4.1540 | 3.2640 |
| PbO | 18.6017 | 17.2685 | ..... | ..... | ..... | ..... |
| $PbO_2$ | 9.9675 | 8.6343 | ..... | ..... | ..... | ..... |
| $SiO_2$ | 2.5025 | 1.1692 | ..... | ..... | ..... | ..... |
| SnO | 11.2250 | 9.9135 | ..... | ..... | ..... | ..... |
| $SnO_2$ | 6.2792 | 4.9460 | ..... | ..... | ..... | ..... |
| $V_2O_5$ | 3.0317 | 2.1381 | 2.5930 | 1.4526 | 2.0232 | 1.1335 |
| $WO_3$ | 6.4444 | 5.1111 | 5.5120 | 4.3716 | 4.3011 | 3.4112 |
| ZnO | 6.7817 | 5.4483 | ..... | ..... | ..... | ..... |

versely affecting rimming action. Aluminum, ferro-titanium or other deoxidizers may also be added in the ladle to control rimming.

If the steel is deoxidized too much, the rimming action will be sluggish. If insufficiently deoxidized, the steel will be too wild in the molds. Mold additions of sodium fluoride stimulate rimming. Mold additions of aluminum reduce the rimming action. Additions of sodium fluoride or fluorspar in the molds may be needed to obtain proper rimming action for steel of relatively high carbon content.

For capped steel, bath conditions at tapping should be similar to those for rimmed steel, but ladle deoxidation should be such that there will be only moderate rimming action, so that the metal will rise in the molds.

*Semi-killed steel* is a compromise between killed and rimmed steels, and is mainly limited to steels going into structural shapes, skelp, plate or sheet bar. It is usually worked in much the same manner as killed steel, with the exception that the lime-silica ratio of the slag may be lower. Unless sulphur troubles occur, semi-killed steels should be tapped with a lime-silica ratio of about 2.2, thus minimizing iron and manganese losses, and saving fluxes.

Here again, ferro-manganese may be added in the furnace or in the ladle, or divided between the two. If large amounts are to be added, at least part must be put in the furnace. Ferro-silicon, ferro-titanium or aluminum may also be added to the ladle for deoxidation.

Deoxidation of semi-killed steels is generally performed in the ladle and mold. It is often preferred to deoxidize principally in the ladle to a point that will permit the desired total deoxidation to be completed by the addition of shot aluminum in the top few inches of the ingot. Deoxidation must be closely controlled to allow limited evolution of gas in the mold. Over-deoxidation will cause the ingots to pipe badly. Under-deoxidation usually means excessive blowhole formation and a thin ingot skin.

*Additions*—In calculating additions, it is essential to consider the weight of metal to be tapped, the residuals in the bath, the analyses of the additions, and the efficiencies to be expected from the additions. The tapped weight includes the metallic charge plus the metallic additions minus the oxidation loss. Residuals are known from the laboratory reports of chemical composition, as are the analyses of additions. The efficiencies obtained from the additions depend on the ease with which the elements are oxidized and the degree of oxidation of the bath when the additions are made. Hence, efficiencies of recovery may vary widely, and it is here that the melter's experience is particularly important, as carbon content, temperature, slag condition and analysis, bath action and time are all factors that must be considered. Table XIV gives ranges of efficiencies for the more common additions.

## TAPPING

When the heat is ready to be tapped, the tap hole is opened up by digging out the mud plug from the back of the furnace and then driving out the dolomite in the hole with a tapping rod inserted through the wicket hole in the center door. If metal has solidified in the tap hole, it may be necessary to burn it out with oxygen.

The runner, which is usually lined with fire clay brick,

**TABLE XVI**

**Weight of Reducing Elements to Reduce One Pound of Metallic Oxide**

| Metallic oxide | Lb of carbon required | Lb of silicon required | Lb of aluminum required |
|---|---|---|---|
| $Cr_2O_3$ | .23676 | .27687 | .35482 |
| FeO | .16703 | .19529 | .25028 |
| $Fe_2O_3$ | .22545 | .26359 | .33780 |
| $Fe_3O_4$ | .20732 | .24240 | .31064 |
| MnO | .16918 | .19780 | .25357 |
| $MnO_2$ | .27608 | .32279 | .41366 |
| $MoO_3$ | .2500 | .29230 | .37458 |
| NiO | .16066 | .18784 | .24073 |
| $V_2O_5$ | .32985 | .38565 | .49423 |
| $WO_3$ | .15517 | .18142 | .23250 |

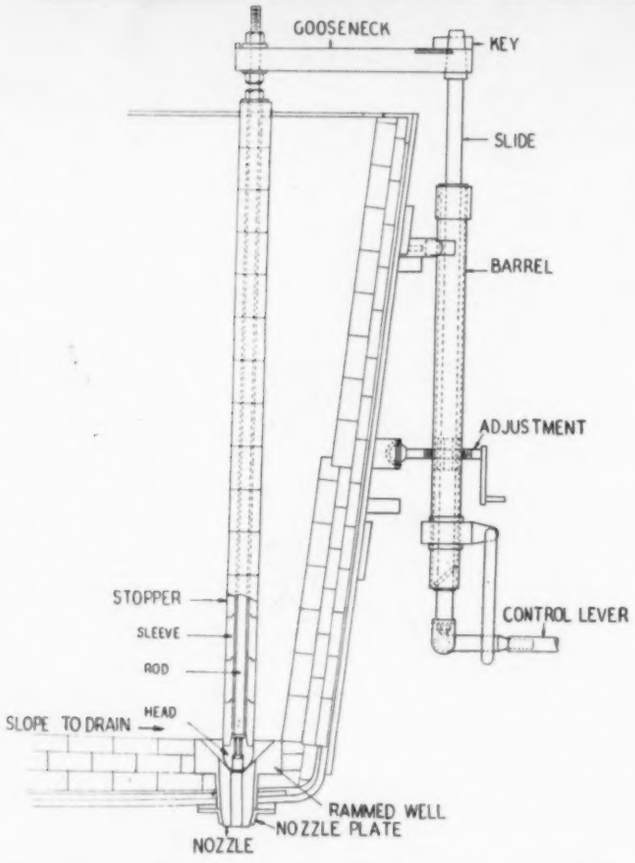



**Figure 29 — This sketch shows the arrangement of the ladle nozzle and stopper, as well as the operating mechanism of the rod.**

should be well mudded over and thoroughly dried out. The joint between the runner and the furnace must be well plugged with fire clay and brick so that there will be no leakage.

Tapping temperatures, as measured by optical pyrometers, should be 2975-3000 F for rimmed steel, and 2900-3000 F for semi-killed and killed steels, the lower temperatures being permissible with the higher carbon steels. The presence of certain alloys, such as chromium, may require higher temperatures than would otherwise be required. Killed and semi-killed steels may be advantageously held in the ladle for 5-15 minutes, if temperature permits, to permit elimination of deoxidation products.

The molten steel (as well as all molten charge material) is handled in ladles by overhead cranes.

*Ladles*—Ladle shells are thimble-shaped or oval, of steel plate 1-1½ in. thick, and of riveted or welded construction, with modern practice favoring the latter. They are usually lined with two separate courses of brick. The first course may be 2-4½ in. thick, of first or second quality fire clay brick, with ¼-⅜ in. of fire clay between the shell and the brick. The second course may be 4½ in. thick, of special ladle brick, laid row-locked. The top foot or two of this second course may be reduced to 2½ in. in thickness, as only slag must be withstood. The bottom lining of ladles may be somewhat thicker than the sides. New linings should be thoroughly dried out, the process requiring 4-12 hr, depending on the type and application of fuel.

An opening about 18 in. square is left unbricked on the bottom of the ladle at the nozzle plate. In this opening the nozzle brick is set, and carefully held straight while dampened fire clay is rammed around it. Some of this rammed material is then cut out to form a well 2-4 in. deep and 12-14 in. in diameter. The nozzle and well should then be dried out with a low flame for an hour or two.

While pouring, the nozzle is opened and closed by a refractory plug or stopper head. This head is mounted on the lower end of a steel rod approximately one foot longer than the height of the ladle. The rod is encased in fire clay sleeve brick for protection from the molten steel. The stopper rod, previously assembled and dried, is carefully set in its operating rig and adjusted so that it seats and closes the nozzle properly, but retains a slight drag toward the back side of the well when lifted. The closure may be tested with fine, screened sand. When proper adjustment is secured, the stopper rod is keyed tight, and the ladle is placed in position on permanent trunnions back of a furnace. A slag thimble is placed to one side so that slag from the ladle will flow into it.

Nozzle and stopper head brick may decrease in weight by 40-50 per cent during the pouring of a heat.

**Figure 30 — When heats are too large for a single ladle, a divided runner and two ladles may be used. A slag pot beside each ladle catches slag as it overflows from the ladle.**

**Figure 31 — Stoppers must be carefully assembled and dried out. This view shows stoppers suspended from a traveling chain conveyor that carries them through a drying oven.**

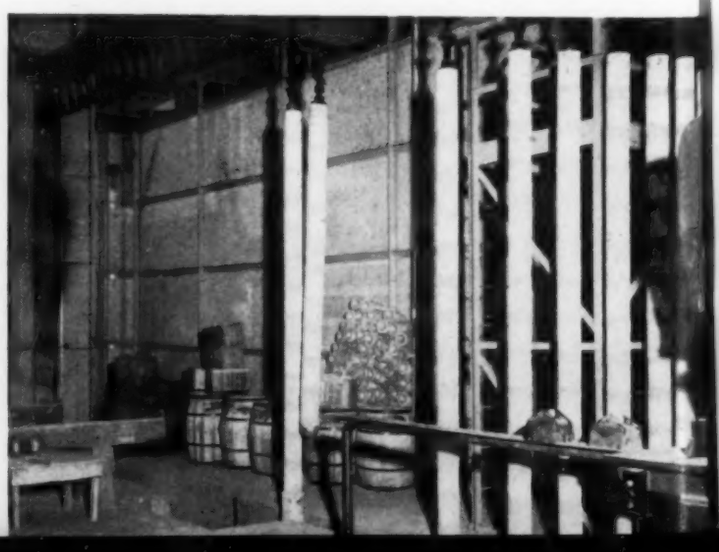


TABLE XVII

Ladle Data

| Capacity, net tons | Dimensions inside shell, ft-in. | | | | | Depth | | | | Lining thickness, in. | | Weight, lb | | | Trunnions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Round | | Oval | | | Metal, ft-in. | | | | | | Ladle | | Lining | Center to center, ft-in. | | |
| | Diameter | Depth | Long diameter | Short diameter | Depth | Round | Oval | Slag, in. | Free space above spout lining, in. | Side | Bottom | Round or oval Riveted | Round or oval Welded | At 145 per cu ft | Round | Oval | Diameter, in. |
| 30 | 7-0 | 6-8 | ..... | ..... | ..... | 5-5 | ..... | 4 | 5 | 6 | 6 | 13,800 | 13,100 | 13,000 | 7-9 | ..... | 7 |
| 40 | 8-4 | 7-6 | ..... | ..... | ..... | 6-2 | ..... | 4 | 6 | 6 | 6 | 14,600 | 14,200 | 14,500 | 9-6 | ..... | 7 |
| 50 | 8-9 | 7-9 | ..... | ..... | ..... | 6-3 | ..... | 4 | 6 | 6 | 8 | 14,900 | 14,800 | 15,500 | 10-0 | ..... | 8 |
| 60 | 9-0 | 8-0 | ..... | ..... | ..... | 6-5 | ..... | 5 | 6 | 6 | 8 | 15,100 | 14,400 | 16,200 | 10-3 | ..... | 9 |
| 70 | 9-3 | 9-6 | ..... | ..... | ..... | 7-10 | ..... | 5 | 6 | 6 | 9 | 17,500 | 16,500 | 22,000 | 10-6 | ..... | 10 |
| 80 | 9-6 | 10-0 | ..... | ..... | ..... | 8-4 | ..... | 5 | 6 | 6 | 9 | 19,000 | 18,200 | 25,500 | 11-0 | ..... | 10 |
| 90 | 10-0 | 10-9 | ..... | ..... | ..... | 8-11 | ..... | 5 | 8 | 6 | 9 | 22,000 | 21,800 | 29,500 | 11-9 | ..... | 12 |
| 100 | 10-3 | 11-1 | ..... | ..... | ..... | 9-0 | ..... | 6 | 8 | 6 | 11 | 40,000 | 37,000 | 34,000 | 12-0 | ..... | 12 |
| 120 | 11-0 | 11-2 | 11-11 | 9-7 | 12-1 | 10-2 | 10-0 | 6 | 8 | 7 | 11 | 43,700 | 40,500 | 38,500 | 13-0 | 11-0 | 14 |
| 140 | 11-8 | 11-2 | 11-9 | 10-6 | 12-3 | 10-2 | 10-8 | 6 | 8 | 7 | 11 | 52,000 | 49,000 | 40,500 | 14-0 | 12-0 | 14 |
| 160 | 12-3 | 12-3 | 13-2 | 10-6 | 11-7 | 10-2 | 9-5 | 6 | 8 | 7 | 11 | 62,000 | 57,400 | 42,000 | 14-6 | 11-3 | 16 |
| 180 | 13-0 | 12-4 | 13-8 | 11-3 | 12-3 | 10-3 | 10-0 | 6 | 8 | 9 | 11 | 76,200 | 69,000 | 46,000 | 15-0 | 12-9 | 16 |
| 200 | 13-4 | 12-4 | 14-1 | 12-0 | 11-10 | 10-3 | 9-9 | 6 | 8 | 9 | 11 | 85,100 | 76,000 | 51,500 | 15-6 | 14-0 | 18 |
| 225 | 13-8 | 12-6 | 14-6 | 12-7 | 12-0 | 10-3 | 9-10 | 6 | 10 | 9 | 11 | 89,700 | 80,000 | 55,000 | 15-10 | 14-9 | 18 |

Ladle capacity ranges from 5 tons up to 225 tons. If heats are larger than can be handled in one ladle, two ladles of equal size are used.

Ladles are normally designed on the basis that molten steel weighs 425 or 430 lb per cut ft, although molten high-alloy steels may weigh considerably more than this. Ladle proportions are somewhat as set forth in Table XVII. Considerable variation is to be expected in such proportions, inasmuch as increases in size of heats in many cases were met by increasing the height of ladles, since existing ladle cranes limited the ladle diameter. Larger heats have also led to oval ladles, which offer greater volume within the same crane hook span, without going to excessive height.

The recent trend seems to be, where possible, toward wider, shallower ladles, which give less hydrostatic pressure at the start of pouring, and seem to produce sounder, more homogeneous ingots.

After pouring a normal heat with no skull, the ladle is allowed to cool for some time, and then cleaned free of adhering slag, inside and out. The lining should be inspected after every heat for erosion, holes and loose brick. If a skull remains in the ladle, the stopper rod and cross-head should be removed as soon as possible, and the ladle turned over. If the skull does not fall out of its own weight, it is allowed to cool and contract, and then pulled out with a cable or punched out with a bar through the nozzle hole.

Ladle linings may last for 12-20 heats, and up to 50-60 heats with special ladle refractories. Refractory consumption for ladle lining normally ranges 20-30 lb per ton of steel.

## POURING

Probably 90 per cent of all steel is top poured, and the steel pourer has much to do with the quality of the ingot surface produced. The stream of metal should be centered over the mold. The stopper should be opened slowly for each mold, so as to form a pool of liquid steel to cushion the full force of the stream. A fan-shaped stream of metal should be avoided. The nozzle should be kept free from any adhering steel, and should be burnt free of steel with oxygen if the steel is skulling in the nozzle. Pressure should be maintained on the stopper rod moving from one mold to another so as to maintain a good closure. Once started, the flow of metal into the mold should never be completely shut off until the mold is filled.

Although many other variables enter into the picture, rate of pouring is generally felt to have a definite effect on ingot surface and soundness. High pouring rates seem to improve ingot surface, while slow pouring tends to produce sounder ingots, and lessen segregation and piping. Pouring rate depends on nozzle orifice diameter, height of metal in the ladle, and fluidity of the steel, the last in turn depending on its grade and temperature. For average conditions with plain carbon steels, pouring rates are approximately as given in Table XVIII.

Pouring rates decrease as the height of steel in the ladle decreases. On the other hand, nozzles tend to cut out and become larger as pouring progresses, thus offsetting to some extent the effect of reduced head.

In order to reduce the high pressure head resulting from high ladles, recourse is sometimes had to the use of a small ladle that receives the steel from the large ladle and in turn pours it into the molds. Such ladles may be 4-6 ft in diameter $\times$ 3-5 ft in height. This practice, which is variously termed double, basket or tun-dish pouring, reduces splashing in molds, and aids in eliminating non-metallic inclusions resulting from deoxidation.

In practice, pouring rates of 150-200 lb per sec seem to prevail. A nozzle of 1¾ in. diameter is widely used,

**Figure 32 — Approximately 90 per cent of steel made in the United States is top-poured. Steel pouring is of vital importance in the production of steel of high quality.**

although nozzles up to 3 or 4 in. in diameter are used for some conditions and grades of steel.

Steel temperature may drop 50-100 F between the furnace spout and the ladle nozzle, and the temperature may drop another 30-100 F between the first and last ingots.

*Killed steel* is almost always poured into hot-topped, big-end-up molds. Many of these molds are of round or polygonal cross-section, because of the favorable effect on ingot structure, and many are fluted or corrugated because of the susceptibility of killed steels to cracking. Molds of this type may have an opening in the bottom that is closed with a clay, steel, or carbon plug before pouring, or they may be cast with closed bottoms.

Proper pouring temperatures (as determined by optical pyrometer) for killed steels of varying carbon content are about as follows:

| Carbon, per cent | Pouring temperature, F |
|---|---|
| 1.20 | 2725-2760 |
| 1.00 | 2760-2800 |
| .80 | 2780-2820 |
| .60 | 2800-2840 |
| .40 | 2820-2860 |
| .20 | 2850-2900 |
| .10 | 2880-2920 |

Certain alloys may change these values somewhat, but from the standpoint of quality alone, killed steel is almost always improved by pouring on the hot side. Low pouring temperatures tend to increase segregation. Very high pouring temperatures seem to cause deeper pipe in the ingots.

The stream of metal should be slackened when the metal rises to the hot top, which should be filled slowly. Some type of thermal insulation may be spread over the top of the ingot to conserve heat. In some cases, heat may be added by gas flame, electric arc or material which reacts exothermically.

*Semi-killed steel* is usually poured into open top, big-end-down molds. No hot top is used. Semi-killed heats should be poured at about the same temperatures as killed heats of the same carbon content.

The important thing in pouring semi-killed steel is to regulate carefully the mold additions of deoxidizers so as to obtain good yield and satisfactory surface.

*Rimmed steel* is almost always poured into open top, big-end-down molds. Temperatures should be slightly higher than for killed and semi-killed steels of the same carbon content, as rimming steel tends to skull more readily. Temperature at the start of pouring should generally be over 2880 F, but excessive temperatures tend to give thinner skinned ingots.

If the rimming action seems too wild, a little shot aluminum may be added. If the action seems sluggish, it may be helped by adding dry fluorspar or sodium fluoride near the bottom of the ingot.

Rimming action may continue for 5-20 minutes after pouring (depending on the analysis and quality of the steel, and on the size of the mold) until the top freezes over or until it is artificially frozen by capping.

Capped steel is usually poured into big-end-down, bottle-top molds, and the rimming action stopped, after a sufficient amount of rim has been obtained, by plac-

**TABLE XVIII**

**Pouring Rates**

| Height of metal in ladle, ft | Pressure on nozzle, psi | Theoretical velocity of metal, fps | Weight of steel poured, lb per sec | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Nozzle diameter, in. | | | | | | |
| | | | 1.25 | 1.50 | 1.75 | 2.00 | 2.50 | 3.0 | 4.0 |
| 14 | 41.6 | 30.0 | 111 | 158 | 216 | 282 | 444 | 632 | 1128 |
| 12 | 35.6 | 27.6 | 102 | 146 | 198 | 261 | 408 | 584 | 1044 |
| 10 | 29.8 | 25.5 | 93 | 135 | 181 | 241 | 372 | 540 | 964 |
| 8 | 23.8 | 22.6 | 83 | 119 | 162 | 213 | 332 | 476 | 852 |
| 6 | 17.8 | 19.6 | 72 | 103 | 140 | 184 | 288 | 412 | 736 |
| 4 | 11.9 | 16.0 | 58 | 84 | 114 | 150 | 232 | 336 | 600 |
| 2 | 5.9 | 11.4 | 42 | 60 | 81 | 107 | 168 | 240 | 428 |
| 1 | 3.0 | 8.0 | 29 | 42 | 57 | 74 | 116 | 168 | 296 |

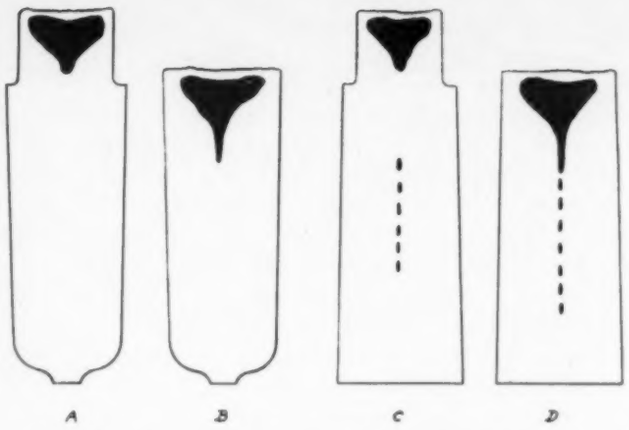



**Figure 33 — These sketches show ingots of killed steel.**

- **A. Big-end-up, hot-topped ingot. The pipe is all contained in the hot-top section. A yield of 80–85 per cent may be obtained.**
- **B. Big-end-up ingot without hot-top. Pipe is confined to upper portion of ingot. Yield will be only 65–70 per cent.**
- **C. Big-end-down, hot-topped ingot. Primary pipe is contained in hot-top section, but secondary pipe or porosity occurs along the central axis. It is impossible to predict what proportion of sound steel will be obtained.**
- **D. Big-end-down ingot without hot-top. Primary pipe extends through 35-40 per cent of the ingots with secondary pipe or porosity along axis. Yield of sound steel may vary widely.**

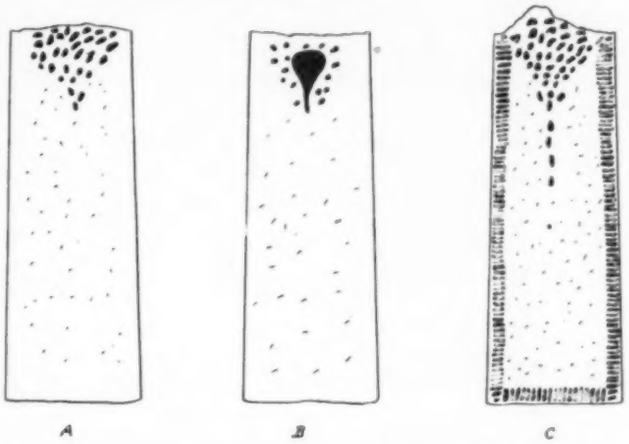



**Figure 34 — These sketches show big-end-down ingots of semi-killed steel.**

- **A. Ingot of good semi-killed steel. Top freezes over with a slight crown or with numerous big blisters indicating that enough gas has been trapped under pressure to prevent primary pipe formation. Yields of 88–92 per cent, free from objectionable porosity, can be obtained.**
- **B. Ingot of steel that has been deoxidized too much, resulting in some primary pipe. Top freezes over smooth and quickly, and may sink slightly. Yield may drop to 80–85 per cent.**
- **C. Ingot of steel that is insufficiently deoxidized. The ingot has bled and built up on top. Pipe is negligible, but there is considerable axial porosity and many blowholes close to the surface. Yield ranges 80 per cent or less.**

ing a tightly-fitting cap on the top of the mold. Approximately the same result may be obtained by "chemically" capping the ingot by adding deoxidizers to the top of the ingot after sufficient rimming time has elapsed.

*Bottom pouring* is used only in special cases where an unusually good ingot surface is desired. In bottom pouring, a number of molds in a group are poured on a special stool. The stool has grooves in which runner brick are placed, with openings arranged for the number of molds in the group. A mold is placed over each opening, and a center pouring fountain is placed in the center of the group, connected with the runner to each mold. Steel is poured into the fountain and flows through the runners into each mold. Thus, steel rises from the bottom of the mold with no splashing and with a relatively slow pouring rate. Bottom pouring gives sound ingots with good surface, but entails about 2 per cent more scrap loss than top pouring. Heats to be bottom poured should be hotter than for top pouring.

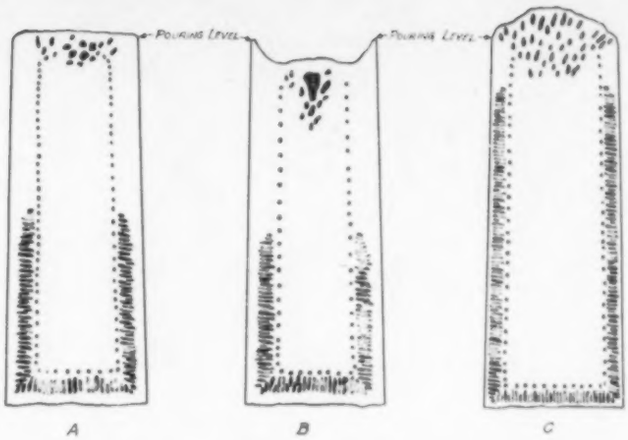



**Figure 35 — These sketches show big-end-down ingots of rimmed steel.**

- **A. Ingot of good rimmed steel. Steel has risen 1 in. or less above poured height. Skin is sound and fairly thick, with some sponginess at the top but no primary pipe. Yield ranges 88–92 per cent.**
- **B. Ingot in which rimming action was too strong, allowing gases to escape rapidly. The top has dropped 3–4 in. from the original poured height. Skin is sound and thick, but some pipe formation will necessitate greater cropping. Yield may range 70–90 per cent.**
- **C. Weak rimming action has resulted in the ingot rising 5–7 in. above poured height. The ingot is thin skinned. Primary blowholes are near the surface and extend over most of the height. Considerable porosity exists at the center. Yield may drop to 60 per cent or less.**

## MOLDS

More than 90 per cent of the ingot molds used are made of blast furnace or cupola iron, while the remain-

**Figure 36 — In bottom pouring, ingots are grouped around a central pouring fountain. The steel flows to each mold through runners in the stool upon which the molds stand.**

der are of cast steel. Analyses of these materials range approximately as follows:

| | Iron | Steel |
|---|---|---|
| Carbon, per cent | 3.5 | .14-.38 |
| Silicon, per cent | 1.3 -1.7 | .07-.40 |
| Manganese, per cent | 1.0 -1.35 | .30-.75 |
| Sulphur, per cent | .04- .05 | .04 |
| Phosphorus, per cent | .12- .15 | .04 |

Ingot shape is usually determined by the subsequent process to be given them. Rolling ingots are generally of square or rectangular shape (except for some types of alloy steels), while forging ingots are generally of a round, corrugated shape. Every ingot shape is a compromise between many factors, including weight, ease of working, fragility of the steel, segregation tendencies, subsequent processing, etc.

Ingot cross-section and weight must be decided upon according to metallurgical requirements, with due consideration to the operating plan of the individual plant. Ingots to be rolled into billets or bars are usually square, while rectangular ingots are more common for flat-rolled products. With rimmed steel, small ingots give a violent rimming action, while large molds freeze so slowly that there is a tendency toward thin skins and porous interiors. Large ingots of rimmed steel are best poured in rectangular slab molds. The cross-section should be such that it will receive a minimum reduction (ingot to rolled product) of 4:1; 6:1 is better.

Molds are tapered from one end to the other so that the top of the ingot is either smaller or larger than the bottom, according to whether the mold is, respectively of big-end-down or big-end-up type. Taper is essential in both types of ingots to facilitate stripping, and in big-end-up ingots, to provide sufficient volume increase from bottom to top so that solidification will be progressively upward. The taper on big-end-down ingots usually ranges 1-2 per cent on each side, while that on big-end-up ingots may be 1.5-2.5 per cent. In some cases the taper is not constant, but may vary somewhat from top to bottom.

Mold wall thickness is important because of its influence on the rate of initial cooling and on the ingot structure. The wall must be thick enough to freeze the molten metal and reduce temperatures below the melting point of cast iron. Some investigators have recommended a wall thickness of about 21 per cent of the ingot thickness. Increasing the thickness of mold walls influences primarily the thickness of the secondary skin of the ingot, rather than the cooling of the interior mass. However, wall thicknesses of more than 4-6 in. seem to be of little value.

The ratio of mold weight to ingot weight may range from .7 up to about 2.0. With ingots of medium weight, molds weigh about the same as the ingots.

The usual relation of ingot length to ingot thickness varies with ingot size, running somewhat as follows:

| Ingot thickness, in. | Average ratio, height : thickness |
|---|---|
| 5 | 6.2 |
| 10 | 5.3 |
| 15 | 4.5 |
| 20 | 3.8 |
| 25 | 3.2 |
| 30 | 2.8 |
| 40 | 2 or less |

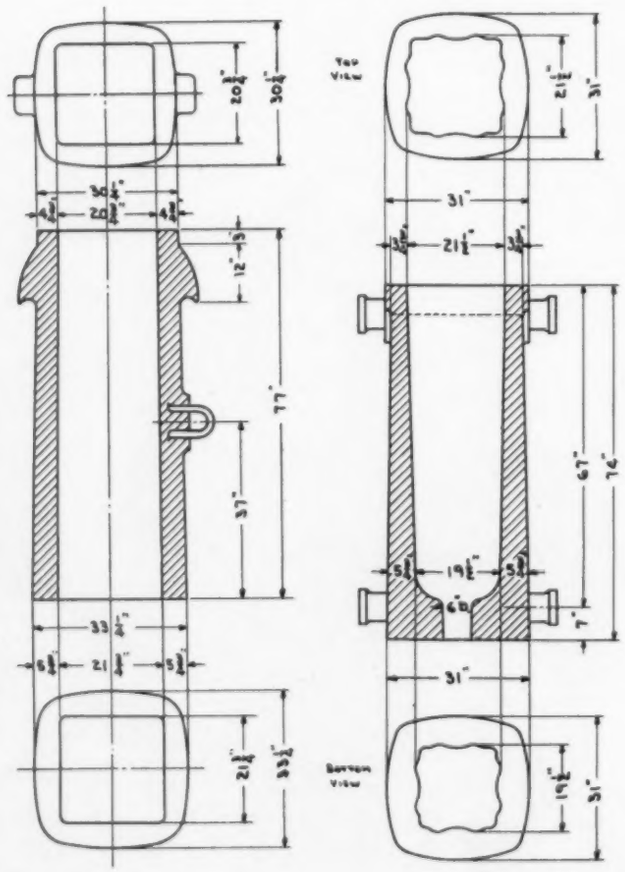
Many operators do not like to have this ratio exceed 3, and feel that even lower values are better. It is generally felt that a height of about 70 in. is maximum if good rimming action is to be obtained.

As an overall average, ingot molds may be said to last about 80 pours. The failures usually arise from burned bottoms, burned corrugations, fire checking, or cracking. Mold consumption, which is generally expressed in pounds of molds, may range 20-95 lb per net ton of ingots. This figure increases with the time the ingots are held in the molds, and it increases with molds of both small and large cross-sectional area. The most favorable cross-sections seem to be between 400 and 1000 sq in. It also increases as the ratio of mold weight to ingot weight exceeds 1.4. The pouring cycle is also important, as molds should be allowed to cool below 350 F before reusing. A good overall average seems to be 35-40 lb of molds per net tons of ingots, although the consumption may exceed this considerably with alloy steels, or with corrugated or rippled mold walls.

Time spent in cleaning and preparing molds is usually an economical practice for almost all grades of steel. Molds should be dry and warm; 200-300 F seems best. After molds have been in service for some time, they should be inspected after every heat for cracks, deep gouges, and scabs.

Mold coatings are widely used, their primary purpose

**Figure 37 — The sketches below show typical ingot molds of (left) big-end-down and (right) big-end-up types.**



being to prevent steel splashes from sticking to the sides of the molds as the steel rises in the molds. A variety of coating material is used, including tar, powdered pitch, sugar, powdered aluminum, and graphite. Tar may be applied by dipping the whole mold into a tar bath, by painting with brushes, or by spraying. Powdered pitch and sugar are usually sprayed on with an air jet. Powdered aluminum suspended in a liquid vehicle may be applied by spray or brush. Graphite is applied by dipping the mold into a graphite wash or by spraying.

Observation of pouring operations clearly show the beneficial effects of mold coating, and records of mold life and of surface defects will also reflect improvement.

Molds ready to be filled stand upon mold stools, which are generally heavy cast iron plates mounted on buggies. For economic reasons, stools should be as small as good operating practice will allow, but, for big-end-down molds, as thick as conditions permit, up to about 15 in. Thus, the stool can cut out considerably before it must be scrapped. Closed-bottom molds eliminate this erosion of stools. Copper stools have been used, but are very expensive. Carbon and graphite stool inserts have also been tried, and are reported to have reduced sticking.

Mold buggies are usually constructed with sides forming aprons that protect running gear and track from molten metal splashes.

## SOLIDIFICATION OF INGOTS

Experiments have shown that the time of solidification of ingots follows the formula:

where D = thickness of metal solidified, in.

$$D = k\sqrt{T}$$

k = .9-1.22, a factor depending on shape and size of the ingot

where T = time after pouring, min.

It must be remembered that D must be considered as only one-half of the smallest dimension of the ingot.

From the foregoing formula, times for solidification of ingots may be approximated as:

| Narrow dimension, in. | Time for complete solidification, hr |
|---|---|
| 12 | .6 |
| 16 | 1.1 |
| 20 | 1.7 |
| 24 | 2.4 |
| 30 | 3.8 |
| 40 | 6.7 |

As molten steel solidifies, it shrinks in volume, and further cooling brings additional shrinkage. Since the surface of the ingot has solidified and cooled considerably long before the center has solidified, both types of shrinkage are present in the ingot at the same time. Shrinkage is therefore the cause of a very important steel-making problem—pipe.

Pipe formation cannot be prevented, but its location and shape can be controlled. If the pipe is shallow and wide, and at the very top of the ingot, maximum yield will be obtained. Killed steel has all of its pipe in one large central cavity, while rimmed capped, and semi-killed ingots have much of their pipe distributed in a spongy area near the top of the ingot. Capped ingots have been found to be somewhat more uniform in

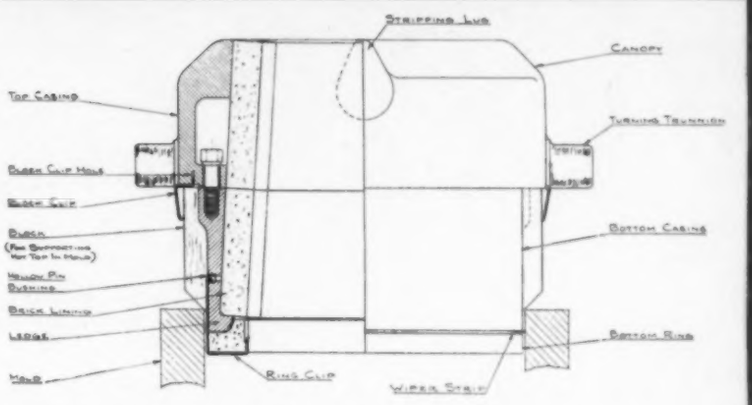



**Figure 38 — This sketch shows a hot top of the permanent type, with refractory lining in a cast steel or iron casing.**

analysis from top to bottom than regular rimmed ingots, and give a slightly higher yield. However, because of the reduced rimming time, blowholes may be closer to the surface, necessitating special care in heating and rolling of ingots of this type. Sound steel yields of 78-82 per cent may be obtained from killed steel ingots cast in hot-topped big-end-up molds, while rimmed and capped steel ingots may give yields of 87-93 per cent. Yields of semi-skilled steel may range 86-92 per cent, but may be much less if the steel is not properly deoxidized. Extremely hot heats of all grades pipe deeper than heats with normal pouring temperatures.

Over 60 per cent of the steel produced is poured in hot-topped molds so as to control piping and increase yields. Originally, hot tops were merely a refractory tile shape set on top of the mold, and were usable only once. At present, hot tops are generally of refractory-lined steel or iron castings. The lining, which is coated with slurry between heats, may last for 25 heats or more.

Hot tops may contain 12-15 per cent of the total ingot weight. Their basic purpose is to maintain a head of molten metal that will be the last part of the ingot to solidify, and thus pull all pipe formation up into the sinkhead.

Other methods of heat conservation have been used to control piping, including the use of electric arcs, gas flames, exothermic chemical reactions, and thermal insulation. With the exception of the last, none of these have been widely adopted for large-scale production of commercial steels.

After ingots have solidified in their molds, the drag of molds is moved to the stripper, which is usually a special type of overhead crane. With big-end-down molds, the mold is lifted from the ingot buggy while a plunger forces the ingot down upon the car. With big-end-up ingots, it is necessary to pull the ingot up while the mold remains on the buggy. Modern stripper cranes, rated at 200 or 250 tons, are usually designed to strip either type of ingots. Normally, the force of gravity is sufficient to effect stripping, but at times, stickers may require the full force of the machine.

Stripper crane motions have approximate speeds of 250-300 fpm on the bridge, 125-150 fpm on the trolley, and 40-45 fpm on the hoist, with a stripping speed of about 10 fpm.

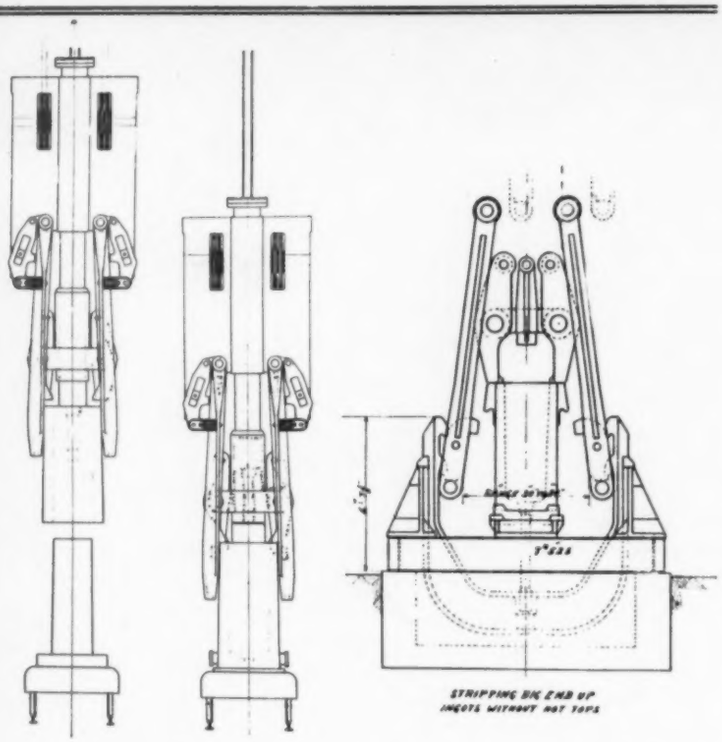


**Figure 39 — These sketches show the operation of a typical stripper crane, stripping respectively (left to right) big-end-down ingots, hot-topped big-end-up ingots, and big-end-up ingots without hot tops.**

*Ingot defects* may be briefly enumerated as follows:

Piping is a cone shaped cavity, small end down, in the top portion of the ingot, caused by contraction during solidification. It varies in size with type of ingot mold and condition of steel, and is reduced by slow pouring, low pouring temperature, rapid cooling, and by use of big-end-up ingots and hot tops.

Blowholes are small cavities formed by bubbles of gas in the metal, and constitute one source of surface seams. They can be lessened by proper deoxidation, and their location can be varied.

Non-metallic inclusions are particles of slag, oxides, etc., caught in the metal as it solidifies. Inclusions may center around blowholes and pipe. They may be lessened by proper choice of deoxidizer and deoxidizing practice, by careful cleaning of the heat in the open hearth, and by keeping the molds free from dirt.

Segregation of metalloids may cause the composition of steel to vary throughout the ingot. It usually occurs close to pipe, and may be lessened by rapid cooling and by use of aluminum.

Ingotism is a peculiar coarse, crystalline structure that may result from poor mold design and improper teeming. It may be lessened by rapid cooling.

Minute internal cracks may result in the centers of dense, hard steels, and are eliminated only by a combination of good melting and pouring practice, with careful cooling of ingots and blooms.

Soft centers are due to rolling the ingot before solidification is completed. An actual cavity may result in the interior when the ingot is laid horizontally on the mill table.

Mold pull or hanger cracks caused by improper mold design (or improper filling), so that the ingot is not free to contract in a longitudinal direction.

Cracks, either surface or internal, may result from bad or sloppy pouring, from too rapid or uneven reheating, or from improper rolling schedule.

Scabs are caused by splashing of steel on the cold wall of the mold.

Checking is a term sometimes applied to transverse skin cracks in the ingot. One cause is interference with the natural contraction of the ingot by rough mold surface, or by molds containing cracks or cavities.

Seams may result in the surface of the rolled bloom from several of the above defects. Blowholes very near the surface may be uncovered during subsequent heating and rolling. It has been said that seams are traceable to silicate stringers in the steel. This may be due to the weakening effect of the non-metallic inclusion, or to the fact that inclusions are prevalent around blowholes. Needless to say, cracks, checks and scabs produce surface defects on the rolled blooms.

## SLAG

The functions of slag are to carry undesirable impurities as they are oxidized from the charge, and to regulate the degree of oxidation of the bath. The formation of a basic slag entails putting into solution enough lime to neutralize the silica, to combine with the phosphorus and sulphur, and to carry the desired amount of iron oxide. Early in the heat, shortly after the hot metal has been added or as the cold iron melts, the silicon, manganese and phosphorus in the metal are oxidized, as previously discussed, and float free of the metal. The resulting oxides, together with iron oxides and small amounts of lime, alumina and magnesia, form the initial slag, which is light, fluid and acid, and consists principally of 2 $FeO.SiO_2$ and 2 $MnO.SiO_2$. It is this slag that is run off to a considerable degree in flush slag practice.

With the subsequent lime boil, slag characteristics change materially. The $CO_2$ given off by calcination of the limestone acts upon the iron of the bath to build up iron oxide in the slag. As sufficient lime becomes available, it replaces the iron oxide and manganese oxide in the silicates, forming $CaO.FeO.SiO_2$ and $CaO.MnO.SiO_2$. As more lime goes into solution, this replacement is completed, forming dicalcium silicate (2 $CaO.SiO_2$).

After all silica present has been taken up as dicalcium silicate, the excess lime begins to react with phosphorus to form calcium phosphate:

$$3\,CaO+P_2O_5=Ca_3P_2O_8$$

and with the sulphur to form calcium sulphide:

$$2\,S+2\,CaO=2\,CaS+O_2$$

When the phosphorus has been supplied, the remaining lime begins to form calcium ferrites ($CaO.Fe_2O_3$, 2 $CaO.Fe_2O_3$ and 3 $CaO.Fe_2O_3$). These compounds, together with free lime and oxides of iron and manganese, exist in the slag at the end of the heat.

The effectiveness of a slag in performing the functions mentioned above is judged by its basicity. Basicity is widely expressed by the ratio of lime to silica. In

some cases, some correction is made for the phosphoric anhydride present, such as the following:

$$V = \frac{CaO}{SiO_2 + P_2O_5}$$

$$V = \frac{CaO - 1.18\ P_2O_5}{SiO_2}$$

$$V = \frac{CaO}{SiO_2 + .634\ P_2O_5}$$

For all practical purposes, however, the simple CaO: $SiO_2$ ratio probably serves just as well.

It is to be seen from the foregoing that the amount of lime required in a heat is governed first by the amount of silicon in the charge, and secondly by the additional amount needed for phosphorus and sulphur removal. One per cent of silicon forms 2.1 per cent silica and requires 4 per cent of lime to form dicalcium silicate. One per cent of phosphorus forms 2.28 per cent $P_2O_5$, which requires 2.7 per cent of lime to form tricalcium phosphate. Additional lime is required for sulphur removal and to maintain the necessary basicity.

Limestone requirements may range from as little as 3.5 per cent with all-scrap or duplexing practices, to as much as 10 per cent or more for hot metal practice and high quality steels. A heat that permits the use of 5 or 6 per cent of limestone may save 1-1½ hr of furnace time over a heat using 10 or 11 per cent of limestone.

During the working of the heat, the slag must be adjusted for phosphorus and sulphur removal, and for oxide control. Burnt lime is generally added to increase basicity, and fluorspar or mill scale to thin the slag. Once the proper lime-silica ratio is obtained, the removal of phosphorus takes place rapidly, and the residual phosphorus of the bath seems to vary little whether the $P_2O_5$ content of the slag is low or high. There is also little trouble with phosphorus reversion with the oxidized grades of steel. As oxidation decreases, however, phosphorus reversion is more apt to occur. Hence, with steels of higher carbon content and lesser degrees of oxidation, the slag must be made more basic. With charges containing 40-45 per cent of hot metal of .25 per cent or less phosphorus, the following lime-silica ratios are typical:

| Type of steel | Lime-silica ratio |
|---|---|
| Rimmed steel | 2.3 |
| Semi-killed steel | 2.4-2.5 |
| Killed steel, under .20 per cent carbon | 2.5-2.7 |
| Killed steel, over .20 per cent carbon | 2.7-3.0 |

These values may vary from plant to plant, and also with the phosphorus content of the charge.

Sulphur removal is relatively slow and rather uncertain in the open hearth process, and its introduction in the iron, scrap, fluxes, fuel and additions should be kept to a minimum. Sulphur removal is facilitated by high lime-silica ratios, and by a fluid slag and good bath action. It is more easily removed when the iron oxide in the slag is comparatively low.

If the sulphur content of the bath is high, early additions of lime are made, and it may be necessary to increase the lime-silica ratio to as much as 4.0. With such highly basic slags, fluorspar will be required to keep them fluid.

When the iron oxide has been released from the silicate compounds, it is free to act as a carrier of oxygen from the flame through the slag to the steel. The commonly accepted theory is that ferrous oxide is oxidized to $Fe_2O_3$ by the flame and travels to the slag-metal face, where it reacts with iron to form more FeO, part of which dissolves in the steel, and part returns to the top of the slag to repeat the cycle. The FeO that dissolves in the steel acts to oxidize silicon, manganese, phosphorus and carbon, and is thereby reduced to iron.

The rate of oxygen transfer, and hence, the rate of elimination of metalloids from the bath, therefore depends upon the amount of iron oxide in the slag, and its ability to travel through the slag, which is a function of viscosity and agitation.

The desired degree of oxidation of the slag and of the steel bath depends on the type of steel to be made. For killed steels, a low degree of oxidation is usually desired, so that minimum quantities of deoxidizers are

**TABLE XIX**

**Typical Open Hearth Slag Analyses**

| | Flush slag from ore heat | Finishing slag from .45 C heat | Finishing slag from .15 C heat | Finishing slag from ingot iron heat | Range of finishing slags |
|---|---|---|---|---|---|
| $SiO_2$ | 20.0 | 17.0 | 15.0 | 9.0 | 9-19 |
| CaO | 10.0 | 45.0 | 48.0 | 40.0 | 36-48 |
| FeO | 37.2 | 11.0 | 13.0 | 28.0 | 9-30 |
| $Fe_2O_3$ | 4.7 | 4.0 | 5.0 | 10.0 | 2-10 |
| MnO | 17.0 | 7.2 | 5.0 | 4.0 | 4-10 |
| $Al_2O_3$ | 2.6 | 3.6 | 3.4 | 1.5 | 2- 5 |
| MgO | 4.3 | 6.8 | 5.4 | 3.4 | 3- 7 |
| $P_2O_5$ | 2.8 | 2.5 | 2.5 | 2.0 | 1- 5 |
| Fe | 1.3 | 2.8 | 2.6 | 2.0 | ..... |
| S | .8 | .1 | .08 | .09 | .05-.40 |

**Figure 40 — Typical modern stripper crane in action on big-end-down ingots.**

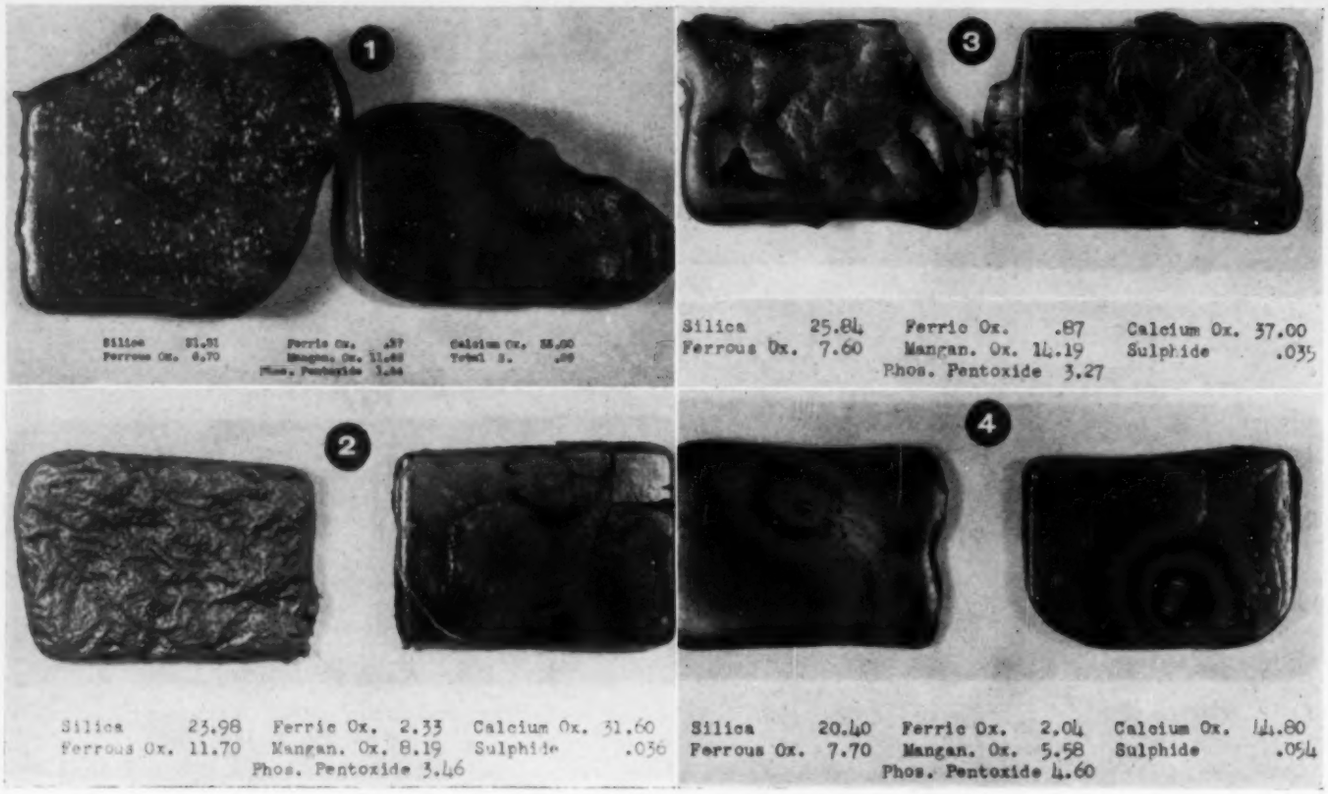



**Figure 41 — The appearance of slag "pan-cakes" provides a valuable guide to the progress of the heat. Slags low in lime-silica ratio present a gray, wrinkled top, while the bottom has an iridescent shine. As the lime-silica ratio increases, the wrinkles gradually disappear but the bottom remains shiny until the ratio reaches 2.4. At this point the bottom of the slag loses its iridescence and becomes dull, an important point in slag control.**

1. **Frost flower slag. Lime-silica ratio = 1.0–1.2. Glassy fracture. Such slags are not prevalent, but occur in the melting down of some scrap processes.**
2. **Creased slag. Lime-silica ratio = 1.2–1.4. Black porous fracture. Bottom is shiny, and flat or convex. Top is rough or creased all over. Creases tend to disappear as V-ratio increases. Oxidizing action mild, as FeO is combined in monticellite.**
3. **Furrowed slag. Lime-silica ratio = 1.4–2.15. Stony, brown fracture indicates low FeO. Bottom is shiny, but not as shiny as in creased slags. Top is furrowed, and gray with lime-silica ratios between 1.4 and 1.6; black with ratios between 1.6 and 2.15. The higher the MnO and the lower the basicity, the deeper the furrows. Oxidizing action is very strong, due to FeO and MnO being uncombined.**
4. **Intermediate slag. Lime-silica ratio = 2.15–2.4. Stony fracture without crystalline structure.**

needed, and inclusions in the steel thus minimized. Ferrous oxide can be held in the slag for a brief time by the addition of burnt lime. The preferred practice for killed steel is to keep the original lime charge on the low side, and then shape up the slag to give a lime-silica ratio of 2.2-2.5. Unless higher basicity is needed for phosphorus and sulphur removal, this ratio may then be maintained until just before furnace deoxidation, when burnt lime is added to bring up the lime-silica ratio to 2.8-4.0.

For rimmed steel, oxidation must be relatively high. Although low carbon (.06 per cent or less) heats may be over-oxidized, heats of higher carbon (.12-.15 per cent) may require definite steps to increase oxidation of the bath, in order to obtain good rimming action in the molds. In such cases, the charge should be sufficiently high in carbon to permit small ore additions or mill scale until shortly before tapping. Many operators state that all rimmed steel heats work better with about 30 lb of iron ore per ton.

Typical finishing slag conditions for rimmed steel are somewhat as follows:

Carbon .12-.15 per cent—2.75-3.5 lime-silica ratio; 16-22 per cent total iron as FeO; fairly heavy additions of burnt lime and iron ore.

Carbon .06-.10 per cent—2.6-3.2 lime-silica ratio; 22-30 per cent total iron as FeO; moderate burnt lime and iron ore additions.

Carbon under .06 per cent—2.8-3.0 lime-silica ratio; 25-40 per cent total iron as FeO, depending on carbon content of heat; ore additions limited to requirements for carbon reduction.

For semi-killed steels, slag is usually kept fluid and of minimum basicity necessary for phosphorus and sulphur removal throughout the heat. Iron ore additions are made only to meet carbon reduction needs, and burnt lime additions are not generally needed.

Open hearth slags contain both FeO and $Fe_2O_3$. One pound of iron forms 1.287 lb of FeO or 1.43 lb of $Fe_2O_3$. The slag samples usually contain some metallic iron also, but this is removed before the slag is analyzed, and hence does not enter into the analysis. Iron oxide in slags may be reported in various ways, with relationships as follows:

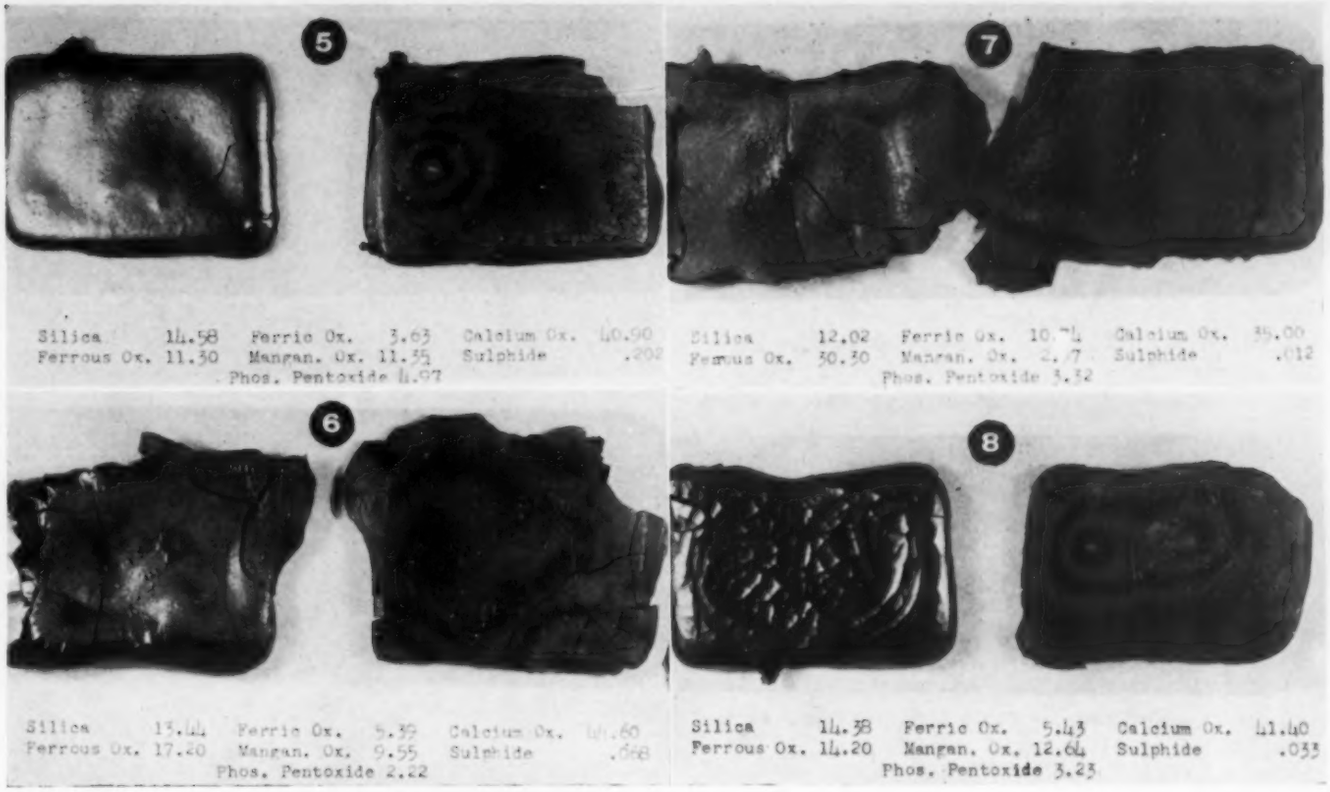
$$\text{FeO} = \text{ferrous iron} \times 1.287$$

$$\text{Fe}_2\text{O}_3 = \text{ferric iron} \times 1.43$$

$$\text{Total iron} = (\text{FeO} \div 1.287) + (\text{Fe}_2\text{O}_3 \div 1.43)$$

$$\text{Total iron as FeO} = \text{total iron} \times 1.287$$
$$= \text{FeO} + .9\ \text{Fe}_2\text{O}_3$$

If the iron oxide content of the slag is high during early stages of the heat, it will probably stay high


5
Silica 14.58 Ferric Ox. 3.63 Calcium Ox. 40.90
Ferrous Ox. 11.30 Mangan. Ox. 11.35 Sulphide .202
Phos. Pentoxide 4.07
7
Silica 12.02 Ferric Ox. 10.74 Calcium Ox. 35.00
Ferrous Ox. 30.30 Mangan. Ox. 2.47 Sulphide .012
Phos. Pentoxide 3.32
6
Silica 13.44 Ferric Ox. 5.39 Calcium Ox. 40.60
Ferrous Ox. 17.20 Mangan. Ox. 9.55 Sulphide .668
Phos. Pentoxide 2.42
8
Silica 14.38 Ferric Ox. 5.43 Calcium Ox. 41.40
Ferrous Ox. 14.20 Mangan. Ox. 12.64 Sulphide .033
Phos. Pentoxide 3.23

**Bottom is shiny. Top is black and shiny, with little evidence of furrows. The flatter and smoother the surface, the lower the MnO. Oxidizing action is mild at the higher basicity due to ferrites combining with calcium.**

5. **Basic slag. Lime-silica ratio over 2.4. Fracture shows striated structure, with glittering grains increasing as iron content increases above 13 per cent. Bottom is dull. Top surfaces are of varied luster, color and design. With lime under 42 per cent and iron under 11 per cent, the top is black, with a high gloss. With lime over 42 per cent and iron under 11 per cent, the top shows a film of dull black coloration. Oxidizing action is strong, and increases with increased basicity.**
6. **Basic slag — with iron at 13–15 per cent, a silvery crystalline film begins to appear on the top of the cake. With 17 per cent iron, about half of the top has become silvery.**
7. **Above 20 per cent iron, the entire top is covered with a silvery sheen, with no indication of the black luster remaining. At the higher basicities, the slags begin to crack and jump.**
8. **Basic Slag — black, glossy and spider webbed top, which appears with a basicity of 2.4–3.6 with high phosphorus pentoxide.**

throughout the heat, as the only way it can be lowered is by depletion through oxidation of carbon or by a large increase in slag volume. If slag is too highly oxidized, the steel will be excessively oxidized, and the steel, if of rimmed grade and not properly deoxidized, will be wild in the molds, or if killed, will contain many inclusions. On the other hand, at least 10 per cent FeO is required in the slag for effective dephosphorization, and too little FeO may allow phosphorus reversion.

In general, iron oxide should be kept as low as is consistent with economical furnace operation. It should be as close to equilibrium with the desired carbon content of the metal as is practical. Desirable relations between basicity and oxidation of slags varies with the carbon content of the steel somewhat as follows:

| C in steel, per cent | Lime-silica ratio | | |
|---|---|---|---|
| | 2.5 | 3.0 | 3.5 |
| | FeO in slag, per cent | | |
| .45 | 11 | 12 | 12 |
| .20 | 12 | 14 | 14 |
| .15 | 13 | 15 | 16 |
| .10 | 17 | 19 | 20 |
| .05 | 23 | 25 | 26 |

For a given carbon content in the steel, iron oxide in the slag may be less with higher metal temperatures.

For maximum production, slag volume should be kept to a minimum, and the slag should be kept relatively fluid. These same conditions will also keep loss of iron in the slag to a minimum. Slag volume may range 90-450 lb per ton of steel, or 4.5-22.5 per cent, depending on the process and materials. Volumes of 150-250 lb per ton (7.5-12.5 per cent) are typical of normal scrap-hot metal practice. Material from the furnace structure may increase the slag volume materially.

The amount of flush slags may vary with the amount of hot metal used in the charge about as follows:

| Per cent of hot metal | Lb of flush slag per ton of steel |
|---|---|
| 50 | 0-50 |
| 62 | 125 |
| 75 | 335 |

A well-charged ore heat should flush with a slag of about .5 lime-silica ratio.

From this brief discussion of slag, it is evident that slag control is essentially concerned with basicity and the degree of oxidation. Slag composition may be determined or estimated by various methods which have been advanced from time to time. Some of these me-

thods have been tried and found wanting. Some have received limited application, while others are widely used.

Chemical analysis, even with rapid methods, requires considerable time. Spectroscopic analysis is faster, but requires skilled operators and expensive equipment. Analytical methods are not widely used for regular control purposes.

Another method of judging slag characteristics entails crushing a slag sample, adding it to water, and, after agitation and soaking, measuring the alkalinity of the solution with a pH meter. This measurement, compared with a calibration curve, gives the basicity of the slag. This method is not used to any great extent.

Slag viscosity is used to some extent as a basis for the evaluation of slag. Probably the best device for measuring slag viscosity is the "viscosimeter" developed by C. H. Herty. This consists of a split steel mold containing a funnel 3 or 4 in. across, feeding into a horizontal tube usually ¼ in. in diameter. Slag is poured rapidly into the funnel, and flows through the tube to a distance depending on the nature of the slag.

The appearance and characteristics of the slag coating remaining on a test rod inserted into the slag is also used as an indication of slag condition.

The appearance of slag pancakes has long been a guide in judging the progress of an open hearth heat, and by correlation with actual analyses, it becomes possible for an experienced man to judge closely the basicity and iron content of the slag. This method is generally used in practical slag control. Round or square pancakes 3 or 4 in. across and ¾ in. thick are generally used.

Characteristics of some general types of slag are given in Figure 41.

## YIELD

In the open hearth process, metal and metalloid losses, including skulls, spillage, etc., may run 7-9 per cent of the charge in the usual scrap and pig process, and up to 15 or 17 per cent with high hot metal charges. The lighter the scrap, the higher the oxidation loss. Phosphorus and manganese in the metallic charge produce losses of their own amounts. Each per cent of carbon eliminated produces a total loss of about 1.2 per cent, and each per cent of silicon produces a loss of 2 per cent. In addition, there is a loss in pouring which in normal practice may range 1-2½ per cent.

In general, open hearth practice gives an ingot yield of 88-90 per cent of the total metallic charge.

Table XX gives a material balance for a simple open hearth heat.

## PRODUCTION RATES

Furnace output depends on the size and design of furnace, the process used, nature of the charge, quality of steel, and of course, the action and efficiency of the furnace. The time of heat may vary from 4 hr for 5-10 ton furnaces up to 8-13 hr for the larger furnaces.

Production rates of open hearth furnaces are expressed in various ways. Tons per furnace-hour is in common use, and these values range 6-22 in practice. Perhaps a better comparison is afforded by the use of tons per hr per 1000 sq ft of hearth area. This factor varies throughout the industry as follows:

| | Net tons per hr per 1000 sq ft of hearth |
|---|---|
| All-cold charge | 14-21 |
| Hot metal-scrap charge | 14-26 |
| Hot metal-blown metal charge | 36-50 |

These figures give rates of 28-42 lb per sq ft for cold charges, 28-52 for hot metal practice, and 72-100 for blown metal practice. Hence, hot metal gives 10-25 per cent more production than cold charges, while blown metal practically doubles the hot metal rate.

Results from one investigation on a small furnace show production rates to vary with the type of charge as follows:

| Per cent of iron charged | Tons per hr with cold iron | Tons per hr with hot metal |
|---|---|---|
| 10 | 8½ | 9¾ |
| 20 | 9¼ | 10⅞ |
| 30 | 9 | 11½ |
| 40 | 8½ | 11¼ |
| 50 | 7¾ | 10½ |

In this instance, maximum production was attained with about 35 per cent of hot metal in the charge, or about 20 per cent of pig iron in the all cold charge.

In the production of high quality killed steels, the furnace practice may include a furnace reboil, which may add about an hour to the heat time, and reduce production accordingly.

The influence of regeneration upon production is important. Production rates may increase as much as 18 per cent as a result of increasing air preheat temperature by 300 F.

Production also drops materially as the furnace becomes older, and may drop to perhaps 80 per cent of the original maximum rate by the time the furnace is due for a rebuild.

The use of oxygen, either to support combustion or for direct carbon elimination, will increase these figures, which are based entirely upon the use of air.

## THE USE OF OXYGEN

Recently, oxygen has received considerable attention as an agent to speed up the open hearth process. It has been used principally in two ways: to support combustion of the fuel, resulting in higher flame temperature, and, bubbled through the bath, to accelerate the rate of reduction.

As a combustion agent, oxygen is generally introduced through the regular furnace burner so that the oxygen jet is below or around the fuel jet. Another method is to introduce the oxygen into the regular air supply coming from the regenerators, but this is not as effective as burner injection. The quantity of oxygen used is usually 20-25 per cent of the total required for combustion of the fuel. This application is useful principally during the melt-down period, when the refractories can withstand the high flame temperature.

Tests in various plants have shown that the time of heats can be decreased by 10-30 per cent by the use of

TABLE XX

Material Balance for Open Hearth Furnace

| Input | Element or radical | Per cent | Per cent of input | Amount, lb per net ton of ingots |
|---|---|---|---|---|
| Pig iron | Fe | 93.46 | 12.54 | 1001.0 |
| | C | 3.80 | .51 | 40.6 |
| | Mn | 1.50 | .20 | 16.1 |
| | Si | 1.00 | .13 | 10.7 |
| | P | .30 | .04 | 3.2 |
| | S | .04 | .00 | .5 |
| | Total | 100.00 | 13.42 | 1072.1 |
| Scrap | Fe | 99.13 | 13.31 | 1063.0 |
| | C | .30 | .04 | 3.2 |
| | Mn | .50 | .07 | 5.3 |
| | P | .03 | .00 | .4 |
| | S | .04 | .00 | .5 |
| | Total | 100.00 | 13.42 | 1072.4 |
| Ore | Fe | 55.0 | .37 | 29.5 |
| | $SiO_2$ | 3.0 | .02 | 1.6 |
| | $Al_2O_3$ | 2.0 | .01 | 1.1 |
| | P | .8 | .00 | .5 |
| | $O_2$ | 29.2 | .20 | 15.6 |
| | $H_2O$ | 10.0 | .07 | 5.3 |
| | Total | 100.0 | .67 | 53.6 |
| Limestone | CaO | 53.7 | 1.02 | 82.3 |
| | MgO | .8 | .02 | 1.2 |
| | $SiO_2$ | 1.5 | .03 | 2.3 |
| | $Al_2O_3$ | .5 | .01 | .8 |
| | $CO_2$ | 43.5 | .84 | 66.5 |
| | Total | 100.0 | 1.92 | 153.1 |
| Raw dolomite | CaO | 31.0 | .26 | 20.7 |
| | MgO | 20.0 | .17 | 13.4 |
| | $SiO_2$ | 1.0 | .01 | .7 |
| | $Al_2O_3$ | 2.0 | .02 | 1.3 |
| | $CO_2$ | 46.0 | .38 | 30.8 |
| | Total | 100.0 | .84 | 66.9 |
| Fuel oil | C | 87.0 | 3.10 | 248.7 |
| | $H_2$ | 12.0 | .43 | 34.4 |
| | S | 1.0 | .04 | 2.9 |
| | Total | 100.0 | 3.57 | 286.0 |
| Steam | $H_2O$ | 100.0 | 1.45 | 116.0 |
| Air | $O_2$ | 21.0 | 13.37 | 1070.0 |
| | $N_2$ | 79.0 | 50.30 | 4020.0 |
| | Total | 100.0 | 63.67 | 5090.0 |
| Moisture in air | $H_2O$ | 100.0 | .82 | 65.2 |
| Furnace structure | $SiO_2$ | 100.0 | .01 | .6 |
| Dirt on charge | $SiO_2$ | 100.0 | .12 | 9.5 |
| Finishing addition | Fe | 20.2 | .02 | 2.6 |
| | Mn | 79.8 | .07 | 10.1 |
| | Total | 100.0 | .09 | 12.7 |
| | Grand Total | | 100.0 | 7998.1 |

| Product | Element or radical | Per cent | Per cent of product | Amount, lb per net ton of ingots |
|---|---|---|---|---|
| Ingots | Fe | 98.80 | 24.62 | 1976.0 |
| | C | .40 | .10 | 8.0 |
| | Mn | .70 | .18 | 14.0 |
| | Si | .03 | .00 | .6 |
| | P | .03 | .00 | .6 |
| | S | .04 | .00 | .8 |
| | Total | 100.00 | 24.90 | 2000.0 |
| Scrap | Fe | 98.80 | .97 | 77.91 |
| | C | .40 | .01 | .04 |
| | Mn | .70 | .01 | .55 |
| | Si | .03 | .00 | .03 |
| | P | .03 | .00 | .03 |
| | S | .04 | .00 | .04 |
| | Total | 100.00 | .99 | 78.60 |
| Slag | $P_2O_5$ | 3.5 | .10 | 7.8 |
| | FeO | 18.1 | .51 | 40.0 |
| | MnO | 7.3 | .20 | 16.2 |
| | $SiO_2$ | 17.9 | .50 | 39.6 |
| | $Al_2O_3$ | 1.3 | .04 | 2.9 |
| | CaO | 45.1 | 1.26 | 99.9 |
| | MgO | 6.6 | .18 | 14.6 |
| | S | .2 | .01 | .5 |
| | Total | 100.0 | 2.80 | 221.5 |
| Flue gas | $CO_2$ | 19.4 | 13.77 | 1097.4 |
| | CO | .4 | .28 | 22.3 |
| | $O_2$ | .6 | .43 | 34.8 |
| | $N_2$ | 70.8 | 50.27 | 4020.0 |
| | $SO_2$ | .1 | .07 | 5.0 |
| | $H_2O$ | 8.7 | 6.18 | 496.0 |
| | Total | 100.0 | 70.90 | 5675.5 |
| Flue dust | FeO | 48.5 | .15 | 10.9 |
| | $SiO_2$ | 10.3 | .03 | 2.3 |
| | CaO | 15.5 | .05 | 3.5 |
| | $Al_2O_3$ | 1.2 | .00 | .3 |
| | MnO | 24.5 | .07 | 5.5 |
| | Total | 100.0 | .30 | 22.5 |
| | Grand Total | | 100.00 | 7998.1 |

oxygen in the furnace burners. Fuel consumption may be decreased by 10-20 per cent. These gains are usually greater in furnaces having relatively low preheat on the combustion air than in furnaces that have a high preheat. Oxygen consumptions range 400-1200 cu ft per ton of steel.

Oxygen injected into the open hearth bath is an effective agent in speeding up carbon reduction. It is injected at 70-100 psi pressure through common ¾ or 1 in. pipe lances or through special water-cooled jets. Tests on this use of oxygen have shown production increases of approximately 10-30 per cent, With this practice, carbon may be reduced at a rate of about one point per minute, with an oxygen flow of 400-700 cu ft per min and a consumption of 100-800 cu ft per ton of steel. The rapid evolution of oxides with this practice may present a dust problem in the waste gases.

The two uses of oxygen have rather definite fields of application. Oxygen as a combustion agent, since it is particularly valuable during meltdown, will show the greatest returns in furnaces using an all-cold furnace charge. Its effect is much less pronounced in furnaces charging large amounts of hot metal. With such charges, on the other hand, injection of oxygen into the bath is particularly advantageous, since large amounts of carbon must be reduced.

Refractory life does not seem to be adversely affected by the use of oxygen to support combustion if care is

used in handling the burner. Injection of oxygen into the bath, however, is reported to cut silica roof life, due to the splashing of molten metal and slag. One plant states that their roof life (silica brick) was reduced by as much as 30 per cent; another puts this figure at 50 per cent. On the other hand, one user reports no refractory damage with conservative use of oxygen lances.

Some experimental work with compressed air and other gases has shown that the accelerated rate of carbon elimination, to a considerable extent, is due to the agitation of the bath and slag, and not just to the reaction between oxygen and carbon. This use of compressed air is being given further study. Also, some use has been made of compressed air to improve combustion, with beneficial results in production and fuel consumption, particularly in smaller furnaces.

## FUEL CONSUMPTION

Fuel consumptions may be found ranging from 2,000,000 up to 6,000,000 or more Btu per net ton of ingots. This is principally dependent on the size and design of furnace, the process used, nature of product and combustion efficiency. In a 200 ton furnace, using hot metal and scrap charges, 3,000,000 Btu per ton represents excellent practice. Figures of 3,500,000 or more Btu per ton are much more common. With all-cold charges, fuel consumptions average about 5,000,000 Btu per ton, while blown metal practice shows figures of about 2,000,000 Btu per ton. The overall average for the industry is approximately 4,200,000 Btu per ton.

As the useful heat in the furnace laboratory is only that above, say, 3000 F, fuel economy must come largely from proper proportioning of fuel and air, efficient regeneration, and reduction of furnace radiation losses.

Combustion in the open hearth must meet varying conditions, and therefore should be easily controllable. In melting down, fuel-air ratios should not be far from the theoretical, as a highly oxidizing flame at this point oxidizes the scrap excessively. With fuel oil, an oxygen content between 1 and 2 per cent in the flue gases (indicating 5-10 per cent excess air) seems best. During the lime boil, some excess air is desirable to combine with the gases (analyzing approximately 70 per cent CO and 30 per cent $CO_2$) given off by the bath. During this time, fuel input may be reduced or the flow of combustion air may be increased.

After the slag has formed, the fuel-air ratio may be adjusted to suit prevailing requirements. The presence of CO above the bath at this time may retard the speed of carbon removal, cause the absorption of sulphur from the fuel by the slag, and, of course, result in a great waste of fuel. On the other hand, a highly oxidizing flame increases oxidation of the bath.

Fuel consumption, as well as flame temperature, is benefited by air preheat temperatures. It is estimated that an increase of 300 F in mean regenerator temperature will cut fuel consumption as much as 20 per cent. As previously mentioned, furnace ends, slag pockets and regenerators should be tightly sealed to keep air infiltration at a minimum on both the incoming and outgoing ends.

Losses through furnace walls may be reduced by the use of thermal insulation on all areas where the temperature and the refractory will permit.

Average fuel input varies with capacity of the furnace somewhat in accordance with the relationship:
Million Btu per hr = 13 + .25 T
where T = capacity of furnace, in net tons.

Actually, the fuel input rate is not a true straight-line relationship, and varies widely on either side of the average. A recent survey shows the following values:

| Furnace capacity, net tons | Average rate of fuel input, million Btu per hr |
|---|---|
| 50 | 20-33 |
| 75 | 23-26 |
| 100 | 30-45 |
| 125 | 40-56 |
| 150 | 43-60 |
| 175 | 46-62 |
| 200 | 55-68 |
| 225 | 57-70 |

Average rate of fuel input may range 70-90 per cent of the maximum input.

Figure 42 shows furnace operating conditions that are typical of good practice in a 200 ton furnace. The oil flow, high during meltdown, is decreased after the hot metal addition, held down during the ore and lime boils, and then stepped up while the heat is worked. Air flow is kept constant until the working period, when it is reduced, as no more carbon monoxide is being given off by bath reactions. Refractory condition, however,

**Figure 42 — This chart shows typical variations of fuel and air input, furnace pressure, and flue gas analyses as used by one major plant.**

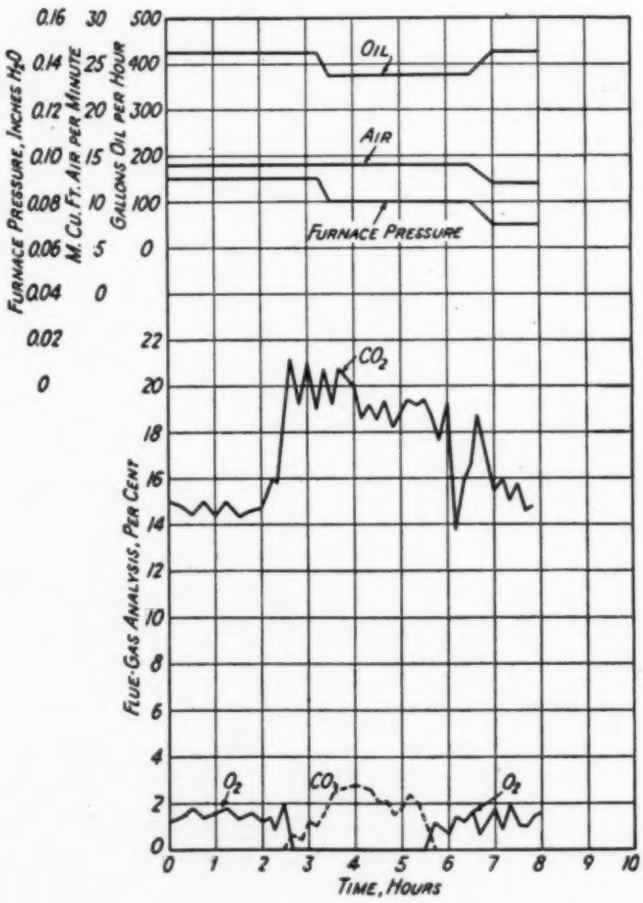


TABLE XXI

Heat Balance of Open Hearth Furnace

| Input | | Btu per net ton of steel | Per cent |
|---|---|---|---|
| 1. Latent heat in fuel, gross | | 3,800,000 | 97.5 |
| 2. Sensible heat in fuel | | 95,000 | 2.5 |
| Total | | 3,895,000 | 100.0 |
| **Output** | | | |
| 3. Heat content of steel tapped | | 1,260,000 | 32.3 |
| 4. Heat content of slag tapped | | 206,000 | 5.3 |
| 5. Calcination of $CaCO_3$ | | 141,000 | 3.6 |
| 6. Calcination of $MgCO_3$ | | 16,000 | .4 |
| 7. Reduction of ore | | 110,000 | 2.8 |
| 8. Heat content of metal charged (—) | | —490,000 | —12.6 |
| 9. Exothermic reactions (—) | | —831,000 | —21.3 |
| Oxidation of Fe | 83,400 | | |
| Oxidation of Mn | 50,000 | | |
| Oxidation of Si | 130,000 | | |
| Oxidation of P | 31,500 | | |
| Oxidation of C | 518,000 | | |
| Formation of $Ca_4P_2O_9$ | 18,100 | | |
| 10. Evaporation and heating $H_2O$ in charge | | 315,000 | 8.1 |
| 11. Loss due to hydrogen in fuel | | 395,000 | 10.1 |
| 12. Loss in dry stack gases | | 1,233,000* | 31.7* |
| 13. Loss due to incomplete combustion | | ..... | ..... |
| 14. Heat into cooling water | | 242,000 | 6.2 |
| 15. Loss through walls, radiation, etc. | | 1,298,000 | 33.4 |
| Total | | 3,895,000 | 100.00 |

*Approximately half of this loss can be reclaimed by waste heat boilers.

Input:

1. Latent heat in fuel = gross heating value of fuel.
2. Sensible heat in fuel = heat content of gaseous fuels + heat content of steam for atomization of liquid fuels.

Output:

3. Heat content of steel tapped = approximately 630 Btu per lb (580-650).
4. Heat content of slag tapped = approximately 930 Btu per lb (820-1050).
5. Calcination of limestone absorbs about 765 Btu per lb of $CaCO_3$.
6. Calcination of $MgCO_3$ absorbs about 550 Btu per lb of $MgCO_3$.
7. Reduction of iron ore absorbs about 2860 Btu per lb of iron, or about 2060 Btu per lb of $Fe_3O_4$.
   Note — Items 5, 6 and 7 may range from nothing up to 300,000 Btu per ton of steel produced, depending on the charge.
8. Heat content of metal charged may be neglected for cold charge. Molten pig iron contains about 490 Btu per lb (450-520). This is taken as a negative item on the output side of the balance.
9. Exothermic reactions. Oxidation of iron (to FeO) gives off 2115 Btu per lb of iron; manganese, 2970 Btu per lb; silicon, 12,150 Btu per lb; and phosphorus, 10,720 Btu per lb. Oxidation of carbon in the charge to $CO_2$ gives off 14,500 Btu per lb of carbon. (This assumes that the CO given off by the bath is burned before leaving the regenerative system, which is included in this balance.) Formation of $Ca_4P_2O_9$ gives off 2040 Btu per lb of calcium. Exothermic reactions usually range 500,000-1,000,000 Btu per ton of steel produced in the scrap and pig process, and up to 1,200,000-1,600,000 Btu per ton of steel for the pig and ore process. This item is taken as negative on the output side of the balance.
10. Evaporation and heating $H_2O$ put into the furnace = (1090 + 0.5 × stack temperature, degrees F) × lb of water, for all that must be evaporated and superheated only.
11. Loss due to hydrogen in fuel = 9 × lb of hydrogen × [ 1090 + 0.5 × (stack temperature—fuel temperature) ]. This item is included only when gross heating value of the fuel is used.
12. Loss in dry stack gases = sensible heat in dry flue gases leaving the regenerative system (approximately .02 Btu per cu ft or .26 Btu per lb per degree F).
13. Loss due to incomplete combustion = heating value of unburned gas leaving the regenerators (approximately 4300 Btu per gal of oil for each per cent of CO in flue gas).
14. Heat into cooling water = lb of water circulated per hr × its temperature rise, F, ÷ rate of furnace production in tons per hr. Water circulation may range up to 2000 gpm per furnace, and its temperature rise may be 20-55 degrees F.
15. Loss through walls, radiation, etc., may be determined by difference. Estimates may be made from the following figures: Heat dissipating surface of furnace laboratory runs 3-4 sq ft per sq ft of hearth area, and its loss averages about 2000 Btu per sq ft per hr. Ports and slag pockets show about 6-8 sq ft of surface per sq ft of hearth area, and its loss averages 1800 Btu per sq ft per hr. Fantails account for about 1.25 sq ft of surface per sq ft of hearth, with a loss of about 1450 Btu per sq ft per hr. Regenertors average 10-12 sq ft of wall surface per sq ft of hearth area. Regenerator surfaces show losses of about 600 Btu per hr per sq ft. Flue areas vary considerably but may average 9-10 sq ft per sq ft of hearth, and lose about 300 Btu per hr per sq ft. Loss through open doors and other openings is estimated at about 200,000 Btu per sq ft per hr. Heat losses through many of the foregoing areas can be reduced by one-third to one-half by heat insulation.

may not permit air flow to be reduced. Furnace pressure is high at the start of the heat, and is decreased as temperature increases in order to save refractories. It must be remembered that the practice shown in this figure is only typical, and cannot be applied indiscriminately.

## HEAT BALANCE

Temperatures prevailing in the open hearth furnace are approximately as follows:

| | Temperature, F |
|---|---|
| Flame temperature | 3200-3600 |
| Flue gas temperature leaving furnace | 2900-3200 |
| Flue gas temperature entering regenerators | 2400-2700 |
| Flue gas temperature leaving regenerators | 1000-1400 |
| Flue gas temperature entering stack (or waste heat boiler) | 900-1200 |
| Flue gas temperature leaving waste heat boiler | 500- 600 |
| Molten pig iron temperature | 2475-2600 |
| Molten steel temperature | 2850-3000 |
| Molten slag temperature | 2900-3050 |
| Furnace roof temperature, inside | 2900-3100 |
| Air entering valves | 50- 100 |
| Air entering regenerators | 250- 350 |

| | |
|---|---|
| Air leaving regenerators | 1700-2000 |
| Air at ports | 1900-2250 |
| Producer gas entering regenerators | 1000-1300 |
| Producer gas leaving regenerators | 1700-2000 |
| Producer gas at ports | 1900-2200 |

Table XXI shows a typical heat balance of an open hearth furnace, and outlines its calculation. It should be noted that this balance is for the entire furnace, including the regenerative system, and not merely for the furnace laboratory. There is also a constant interchange of heat between the hearth and the regenerators, through the medium of the waste gases and the preheated air. In this example, the preheated air would contain about 1,250,000 Btu per net ton of steel.

## THE ACID PROCESS

The acid open hearth differs from the basic furnace, in that the refractory materials are all of the acid type. The hearth consists of silicious material burned into place.

The initial charge in this process is usually cold pig iron and scrap. Since the acid process removes only carbon, manganese and silicon, the material charged must be low in phosphorus and sulphur. The iron should contain 2.0 per cent or less silicon, and 1.50-1.75 per cent manganese, with phosphorus and sulphur under .03 per cent.

The acid heat requires little attention during the melt-down, which may take 4 or 5 hr. When the charge is completely molten, most of the manganese and silicon are oxidized and in the slag. This slag is essentially acid in nature, containing about 50 per cent silica, with the remainder principally iron and manganese oxides. Slag adjustments may be made by the addition of iron ore, lime or silica sand.

The carbon content, which at melting may be about .50 per cent above that required in the steel, is worked down by the addition of iron ore to a point under that required in the finished steel. Little or no ore is added toward the end of the heat, so that the remaining carbon feeds off of the oxide in the bath, thus acting to deoxidize the steel.

When the heat is ready, it is tapped, and recarburizers and deoxidizers added in the ladle. Anthracite coal and ferro-manganese are the usual materials. Other alloys may be added in the ladle or in the furnace, as in the basic process.

The steel is teemed just as in the basic process. If the steel is insufficiently deoxidized, aluminum may be added in the mold.

In the acid process, the composition and nature of the slag can be easily controlled, and the metal is less oxidized. Hence, it is easier to consistently produce a uniform product. The low phosphorus and sulphur requirement of the charge, however, is difficult to meet with the materials available. Also, it is quite difficult to produce rimmed steel by the acid process, due to the low degree of oxidation of the bath.

At present, the United States' production of acid open hearth steel is approximately 1¼ million tons per year.

## SERVICES

Electric power requirements for an open hearth shop may range 3-4 kwhr of d-c power per ton of steel produced, exclusive of pumps and fans. It is used by cranes, charging machines, door hoists, etc. Figured at 75 per cent conversion efficiency, this gives 4.0-5.5 kwhr of a-c power per ton of steel.

Open hearth shops usually employ 15-20 motors per furnace, ranging 300-500 connected hp per furnace, or 3-6 hp per ton of furnace capacity. The ratio of average kw consumption to connected hp is usually 13-14 per cent.

Water consumption may range up to 2000 gpm in a large furnace. On a tonnage basis, consumptions are found ranging up to 6000 gal per ton of steel produced.

Steam is used for heating, pumping and atomizing liquid fuel. Usual steam consumptions found in open hearth plants are 6-8 lb of steam per gal of liquid fuel or 175-250 lb of steam per ton of steel produced for straight oil-fired furnaces. Atomizing the liquid fuel requires 3 or 4 lb of steam per gal of fuel. Pumping, with steam-driven duplex pumps, requires .5-1.0 lb of steam per gal. Heating is usually accomplished in several stages and may require 1-3 lb of steam per gal, depending principally upon weather conditions.

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# APPENDIX

| Company | No. of furnaces | Acid or Basic | Rated capacity per heat | Annual capacity net tons |
|---|---|---|---|---|
| **Alan Wood Steel Company** | | | | |
| Ivy Rock, Plant | | | | |
| Ivy Rock, Pennsylvania | 7 | B | 112 | 550,000 |
| **Allegheny Ludlum Steel Corporation** | | | | |
| Brackenridge Plant | | | | |
| Brackenridge, Pennsylvania | 1 | B | 55 | 24,000 |
| | 1 | B | 85 | 42,000 |
| | 1 | B | 95 | 33,000 |
| | 1 | B | 100 | 44,000 |
| | 2 | B | 110 | 92,000 |
| | 1 | A | 35 | 20,160 |
| Total | 7 | | | 260,160 |
| **American Locomotive Company** | | | | |
| Inter-Ocean Works | | | | |
| Chicago Heights, Illinois | 3 | B | 50 | 100,000 |
| Latrobe Works | | | | |
| Latrobe, Pennsylvania | 3 | A | 50 | 100,000 |
| Total | 6 | | | 200,000 |
| **Armco Steel Corporation** | | | | |
| Ashland Division | | | | |
| Ashland, Kentucky | 6 | B | 132 | 599,430 |
| | 2 | B | 151 | 228,570 |
| | 8 | | | 828,000 |
| Butler Division | | | | |
| Butler, Pennsylvania | 4 | B | 112 | 236,020 |
| | 1 | B | 118 | 62,166 |
| | 2 | B | 127 | 133,814 |
| | 7 | | | 432,000 |
| Middletown Division | | | | |
| Middletown, Ohio | 4 | B | 128 | 430,760 |
| | 4 | B | 143 | 481,240 |
| | 8 | | | 912,000 |
| Total | 23 | | | 2,172,000 |
| **Atlantic Steel Company** | | | | |
| Atlanta Works | | | | |
| Atlanta, Georgia | 3 | B | 74 | 165,000 |
| **Baldwin Locomotive Works** | | | | |
| Burnham Works | | | | |
| Burnham, Pennsylvania | 4 | A | 62 | 119,425 |
| | 1 | A | 100 | 50,485 |
| Total | 5 | | | 169,910 |

| Company | No. of furnaces | Acid or Basic | Rated capacity per heat | Annual capacity net tons |
|---|---|---|---|---|
| **Barium Steel & Forge, Inc.** | | | | |
| Canton Works | | | | |
| Canton, Ohio | 1 | B | 35 | 20,870 |
| | 1 | B | 35 | 20,870 |
| Total | 2 | | | 41,740 |
| **Bethlehem Steel Company** | | | | |
| Bethlehem Plant | | | | |
| Bethlehem, Pennsylvania | 5 | B | 101 | 340,000 |
| | 16 | B | 123 | 1,321,000 |
| | 1 | B | 125 | 78,000 |
| | 5 | B | 190 | 666,000 |
| | 1 | A | 17 | |
| | 1 | A | 22 | |
| | 1 | A | 60 | 22,000 |
| | 1 | A | 70 | |
| | 1 | A | 80 | |
| | 32 | | | 2,427,000 |
| Johnstown Plant | | | | |
| Johnstown, Pennsylvania | 15 | B | 106 | 1,143,000 |
| | 6 | B | 123 | 497,000 |
| | 21 | | | 1,640,000 |
| Lackawanna Plant | | | | |
| Lackawanna, New York | 14 | B | 112 | 1,284,000 |
| | 2 | B | 118 | 198,000 |
| | 8 | B | 123 | 750,000 |
| | 6 | B | 168 | 888,000 |
| | 30 | | | 3,120,000 |
| Los Angeles Plant | | | | |
| Los Angeles, California | 3 | B | 50 | 117,000 |
| Seattle Plant | | | | |
| Seattle, Washington | 5 | B | 45 | 210,000 |
| South San Francisco Plant | | | | |
| South San Francisco, California | 5 | B | 56 | 235,000 |
| Sparrows Point Plant | | | | |
| Sparrows Point, Maryland | 9 | B | 146 | 1,177,200 |
| | 19 | B | 168 | 3,161,800 |
| | 28 | | | 4,339,000 |

| Company | No. of furnaces | Acid or Basic | Rated capacity per heat | Annual capacity net tons |
|---|---|---|---|---|
| **Bethlehem Steel Company (continued)** | | | | |
| Steelton Plant | | | | |
| Steelton, Pennsylvania | 6 | B | 95 | 488,400 |
| | 3 | B | 123 | 377,600 |
| | 1 | A | 22 | 20,000 |
| | 1 | A | 28 | |
| | 11 | | | 886,000 |
| Total | 135 | | | 12,974,000 |
| **Byers Company, A. M.** | | | | |
| Byers Works | | | | |
| Ambridge, Pennsylvania | 2 | B | 40 | 75,000 |
| **Central Iron & Steel Company** | | | | |
| Harrisburg Works | | | | |
| Harrisburg, Pennsylvania | 5 | B | 115 | 288,000 |
| **Colorado Fuel and Iron Corporation** | | | | |
| Minnequa Works | | | | |
| Pueblo, Colorado | 16 | B | 107 | 1,272,000 |
| Wickwire-Spencer Steel Division | | | | |
| Buffalo, New York | 4 | B | 100 | *268,000 |
| Total | 20 | | | 1,540,000 |
| *Based on 120 total furnace days down for repairs. | | | | |
| **Continental Steel Corporation** | | | | |
| Kokomo Works | | | | |
| Kokomo, Indiana | 5 | B | 125 | 364,000 |
| **Crucible Steel Company of America** | | | | |
| Park Works | | | | |
| Pittsburgh, Pennsylvania | 3 | B | 60 | 109,068 |
| | 1 | A | 60 | 33,787 |
| | 4 | | | 142,855 |
| Pittsburgh Crucible Division | | | | |
| Midland, Pennsylvania | 12 | B | 112 | 793,200 |
| Total | 16 | | | 936,055 |
| **Edgewater Steel Company** | | | | |
| Oakmont Works | | | | |
| Oakmont, Pennsylvania | 1 | B | 35 | 27,080 |
| | 2 | B | 84 | 90,410 |
| | 1 | A | 20 | 22,680 |
| Total | 4 | | | 140,170 |
| **Empire Steel Corporation** | | | | |
| Mansfield Works | | | | |
| Mansfield, Ohio | 2 | B | 95 | |
| | 2 | B | 125 | 367,750 |
| | 2 | B | 125 | |
| Total | 6 | | | 367,750 |
| **Erie Forge Company** | | | | |
| Erie Works | | | | |
| Erie, Pennsylvania | 2 | A | 70 | 80,000 |
| | 1 | A | 80 | |
| Total | 3 | | | 80,000 |
| **Erie Forge & Steel Company** | | | | |
| Erie Works | | | | |
| Erie, Pennsylvania | 2 | A | 75 | 128,950 |
| **Follansbee Steel Corporation** | | | | |
| Toronto Works | | | | |
| Toronto, Ohio | 4 | B | 48 | 141,000 |

| Company | No. of furnaces | Acid or Basic | Rated capacity per heat | Annual capacity net tons |
|---|---|---|---|---|
| **Ford Motor Company** | | | | |
| Dearborn Works | | | | |
| Dearborn, Michigan | 5 | B | 180 | |
| | 2 | B | 180 | 982,812 |
| | 3 | B | 110 | |
| Total | 10 | | | 982,812 |
| **Granite City Steel Company** | | | | |
| Granite City Works | | | | |
| Granite City, Illinois | 10 | B | 67 | |
| | 3 | B | 180 | 620,000 |
| Total | 13 | | | 620,000 |
| **Harrisburg Steel Corporation** | | | | |
| Harrisburg Works | | | | |
| Harrisburg, Pennsylvania | 3 | B | 45 | 100,750 |
| **Heppenstall Company** | | | | |
| Pittsburgh Works | | | | |
| Pittsburgh, Pennsylvania | 2 | A | 40 | 56,000 |
| **Inland Steel Company** | | | | |
| Indiana Harbor Works | | | | |
| Indiana Harbor, Indiana | 12 | B | 90 | 919,000 |
| | 15 | B | 145 | 1,439,000 |
| | 9 | B | 175 | 1,042,000 |
| Total | 36 | | | 3,400,000 |
| **International Detrola Corporation** | | | | |
| Newport Works | | | | |
| Newport, Kentucky | 2 | B | 95 | 106,000 |
| | 5 | B | 112 | 307,100 |
| Total | 7 | | | 413,100 |
| **International Harvester Company** | | | | |
| Wisconsin Steel Works | | | | |
| South Chicago, Illinois | 9 | B | 112 | 715,000 |
| | 2 | B | 168 | 185,000 |
| Total | 11 | | | 900,000 |
| **Jones & Laughlin Steel Corporation** | | | | |
| Aliquippa Works | | | | |
| Aliquippa, Pennsylvania | 4 | B | 150 | 1,077,000 |
| | 1 | B | 150 | 105,000 |
| | 5 | | | 1,182,000 |
| Otis Works | | | | |
| Cleveland, Ohio | 8 | B | 175 | 840,000 |
| Pittsburgh Works | | | | |
| Pittsburgh, Pennsylvania | 1 | B | 56 | |
| | 3 | B | 67 | 156,000 |
| | 6 | B | 62 | 270,000 |
| | 4 | B | 225 | 530,400 |
| | 5 | B | 168 | 969,600 |
| | 1 | A | 30 | 30,000 |
| | 20 | | | 1,956,000 |
| Total | 33 | | | 3,978,000 |
| **Judson Steel Corporation** | | | | |
| Emeryville Works | | | | |
| Emeryville, California | 3 | B | 30 | 76,500 |
| **Kaiser Company, Inc.** | | | | |
| Fontana Works | | | | |
| Fontana, California | 6 | B | 185 | 840,000 |
| **Keystone Steel & Wire Company** | | | | |
| South Bartonville Works | | | | |
| Peoria, Illinois | 3 | B | 165 | 302,400 |

| Company | No. of furnaces | Acid or Basic | Rated capacity per heat | Annual capacity net tons |
|---|---|---|---|---|
| Laclede Steel Company | | | | |
| Alton Works | | | | |
| Alton, Illinois | 1 | B | 134 | 77,170 |
| | 1 | B | 140 | 78,750 |
| | 2 | B | 162 | 170,100 |
| Total | 4 | | | 326,020 |
| Lukens Steel Company | | | | |
| Coatesville Works | | | | |
| Coatesville, Pennsylvania | 6 | B | 90 | 273,666 |
| | 6 | B | 123 | 350,334 |
| Total | 12 | | | 624,000 |
| Mesta Machine Company | | | | |
| West Homestead Works | | | | |
| West Homestead, Pennsylvania | 2 | A | 50 | 28,050 |
| | 1 | A | 80 | 22,100 |
| | 1 | A | 125 | 34,850 |
| Total | 4 | | | 85,000 |
| Midvale Company | | | | |
| Nicetown Works | | | | |
| Nicetown, Philadelphia, Pennsylvania | 1 | B | 84 | 41,570 |
| | 1 | B | 100 | 49,450 |
| | 2 | B | 100 | 98,900 |
| | 2 | A | 90 | 113,900 |
| | 2 | A | 100 | 127,010 |
| Total | 8 | | | 430,830 |
| National Steel Corporation | | | | |
| Great Lakes Steel Corporation | | | | |
| Detroit, Michigan | 16 | B | 200 | 2,100,000 |
| Weirton Steel Company | | | | |
| Weirton, West Virginia | 6 | B | 200 | 1,95000 |
| | 5 | B | 380 | |
| | 1 | B | 400 | |
| | 12 | | | 1,950,000 |
| Total | 28 | | | 4,050,000 |
| Phoenix-Apollo Steel Company | | | | |
| Phoenixville Works | | | | |
| Phoenixville, Pennsylvania | 2 | B | 125 | 87,750 |
| | 4 | B | 150 | 223,650 |
| Total | 6 | | | 311,400 |
| Pittsburgh Steel Company | | | | |
| Monessen Works | | | | |
| Monessen, Pennsylvania | 12 | B | 140 | 1,072,000 |
| Portsmouth Steel Corporation | | | | |
| Portsmouth Works | | | | |
| Portsmouth, Ohio | 10 | B | 85 | 616,000 |
| Republic Steel Corporation | | | | |
| Buffalo Works | | | | |
| Buffalo, New York | 5 | B | 110 | 370,000 |
| | 3 | B | 220 | 345,000 |
| | 1 | B | 250 | 115,000 |
| | 9 | | | 830,000 |
| Canton Works | | | | |
| Canton, Ohio | 3 | B | 110 | 265,000 |
| | 3 | B | 110 | * |
| | 6 | | | 265,000 |
| Republic Steel Company (continued) | | | | |
| Cleveland Works | | | | |
| Cleveland, Ohio | 5 | B | 185 | 510,000 |
| | 9 | B | 195 | 990,000 |
| | 14 | | | 1,500,000 |
| Gulfsteel Works | | | | |
| Gadsden, Alabama | 5 | B | 140 | 375,000 |
| | 1 | B | 150 | 85,000 |
| | 2 | B | 175 | 190,000 |
| | 8 | | | 650,000 |
| Massillon Works | | | | |
| Massillon, Ohio | 7 | B | 95 | 465,000 |
| | 2 | B | 110 | 145,000 |
| | 9 | | | 610,000 |
| South Chicago Works | | | | |
| South Chicago, Illinois | 2 | B | 85 | 110,000 |
| | 6 | B | 110 | 390,000 |
| | 3 | B | 200 | 337,500 |
| | 1 | B | 225 | 137,500 |
| | 12 | | | 975,000 |
| Warren District Works | | | | |
| Warren, Ohio | 8 | B | 190 | 860,000 |
| Youngstown Works | | | | |
| Youngstown, Ohio | 4 | B | 125 | 300,000 |
| | 2 | B | 135 | 160,000 |
| | 9 | B | 195 | 990,000 |
| | 15 | | | 1,450,000 |
| Total | 81 | | | 7,140,000 |
| Reobling's Sons Company, John A. | | | | |
| Kinkora Works | | | | |
| Roebling, New Jersey | 2 | B | 40 | 50,900 |
| | 7 | A | 40 | 202,100 |
| Total | 9 | | | 253,000 |
| Sharon Steel Corporation | | | | |
| Farrell Steel Works | | | | |
| Farrell, Pennsylvania | 14 | B | 115 | 1,110,000 |
| Lowellville Works | | | | |
| Lowellville, Ohio | 5 | B | 150 | 500,000 |
| Total | 19 | | | 1,610,000 |
| Sheffield Steel Corporation | | | | |
| Houston, Texas | 6 | B | 146 | 560,000 |
| Sheffield Steel Corporation | | | | |
| Kansas City Works | | | | |
| Kansas City, Missouri | 5 | B | 126 | 426,000 |
| Sand Springs Works | | | | |
| Sand Springs, Oklahoma | 1 | B | 73 | 54,000 |
| Total | 6 | | | 480,000 |
| Stanley Works, The | | | | |
| American Tube & Stamping Plant | | | | |
| Bridgeport, Connecticut | 2 | B | 62 | 107,040 |
| | 1 | B | 112 | 81,240 |
| Total | 3 | | | 188,280 |
| Timken Roller Bearing Company | | | | |
| Canton Works | | | | |
| Canton, Ohio | 3 | B | 112 | 201,600 |

*3 furnaces used to produce remelt steel for electric furnace charge.

| Company | No. of furnaces | Acid or Basic | Rated capacity per heat | Annual capacity net tons |
|---|---|---|---|---|
| **United States Steel Corporation** | | | | |
| American Steel & Wire Company | | | | |
| Donora, Pennsylvania | 13 | B | 110 | 842,000 |
| Duluth Works | | | | |
| Duluth, Minnesota | 7 | B | 125 | 690,000 |
| South Works | | | | |
| Worcester, Massachusetts | 4 | B | 85 | 250,000 |
| Total | 24 | | | 1,782,000 |
| Carnegie-Illinois Steel Corporation | | | | |
| Clairton Steel Works | | | | |
| Clairton, Pennsylvania | 12 | B | 101 | 805,000 |
| Duquesne Steel Works | | | | |
| Duquesne, Pennsylvania | 9 | B | 78 | 355,584 |
| | 6 | B | 90 | 244,416 |
| | 12 | B | 118 | 1,000,000 |
| | 27 | | | 1,600,000 |
| Edgar Thomson Steel Works | | | | |
| Braddock, Pennsylvania | 10 | B | 170 | 1,154,500 |
| | 6 | B | 130 | 598,500 |
| | 16 | | | 1,753,000 |
| Gary Steel Works | | | | |
| Gary, Indiana | 1 | B | 11 | 4,800 |
| | 1 | B | 28 | 12,000 |
| | 42 | B | 144 | 3,837,000 |
| | 8 | B | 183 | 930,000 |
| | 3 | B | 224 | 875,000 |
| | 55 | | | 5,718,800 |
| Homestead Steel Works | | | | |
| Munhall, Pennsylvania | 8 | B | 50 | 240,504 |
| | 4 | B | 62 | 123,712 |
| | 21 | B | 73 | 957,584 |
| | 3 | B | 95 | 184,200 |
| | 14 | B | 119 | 1,073,000 |
| | 11 | B | 225 | 1,700,000 |
| | 61 | | | 4,279,000 |
| Johnstown-Lorain Works | | | | |
| Johnstown, Pennsylvania | 2 | A | 22 | 18,900 |
| Ohio Steel Works | | | | |
| Youngstown, Ohio | 15 | B | 135 | 1,560,000 |
| South Steel Works | | | | |
| South Chicago, Illinois | 14 | B | 112 | 1,140,000 |
| | 14 | B | 168 | 1,740,000 |
| | 3 | B | 224 | 875,000 |
| | 31 | | | 3,755,000 |
| Vandergrift Works | | | | |
| Vandergrift, Pennsylvania | 12 | B | 70 | 500,000 |
| Total | 231 | | | 19,989,700 |
| **Columbia Steel Company** | | | | |
| Pittsburg Works | | | | |
| Pittsburg, California | 2 | B | 25 | 37,900 |
| | 4 | B | 80 | 244,300 |
| | 1 | B | 90 | 71,700 |
| | 7 | | | 353,900 |
| **Columbia Steel Company (continued)** | | | | |
| Torrance Works | | | | |
| Torrance, California | 4 | B | 58 | 201,700 |
| Total | 11 | | | 555,600 |
| **Geneva Steel Company** | | | | |
| Geneva Works | | | | |
| Geneva, Utah | 9 | B | 225 | 1,283,400 |
| **National Tube Company** | | | | |
| Lorain Works | | | | |
| Lorain, Ohio | 12 | B | 156 | 1,326,000 |
| National Works | | | | |
| McKeesport, Pennsylvania | 3 | B | 224 | 876,000 |
| Total | 15 | | | 2,202,000 |
| **Tennessee Coal, Iron & Railroad Company** | | | | |
| Ensley Works | | | | |
| Ensley, Alabama | 9 | B | 143 | 1,568,000 |
| Fairfield Works | | | | |
| Fairfield, Alabama | 2 | B | 33½ | 52,000 |
| | 10 | B | 190 | 1,326,000 |
| Total | 21 | | | 2,946,000 |
| Total — United States Steel Corporation | 311 | | | 28,758,700 |
| **Washburn Wire Company** | | | | |
| Phillipsdale Works | | | | |
| Phillipsdale, Rhode Island | 3 | B | 22 | 60,000 |
| **Wheeling Steel Corporation** | | | | |
| Steubenville Works | | | | |
| Steubenville, Ohio | 11 | B | 160 | 1,073,000 |
| **Wickwire Brothers, Inc.** | | | | |
| Cortland Works | | | 30 | |
| Cortland, New York | 3 | B | | 38,000 |
| **Worth Steel Company** | | | | |
| Claymont Works | | | | |
| Claymont, Delaware | 7 | B | 112 | 460,000 |
| **Youngstown Sheet and Tube Company** | | | | |
| Brier Hill Works | 12 | | | |
| Youngstown, Ohio | | B | 125 | 1,104,000 |
| Campbell Works | 12 | | | |
| Campbell, Ohio | | B | 140 | 1,212,000 |
| Indiana Harbor Works | 2 | | | |
| East Chicago, Indiana | 7 | B | 175 | 223,570 |
| | | B | 200 | 892,430 |
| | 9 | | | 1,116,000 |
| Total | 33 | | | 3,432,000 |
| Total — All United States Companies | 961 | | | 84,033,127 |

# *This mold can slash your costs . . .*

## Thin walls *plus* longer life!

LOOK into this mold. Here is a big-end-up design that will give you the excellence of product you hope for, *plus* low molding costs.

This Gathmann thin-wall multi-taper mold is now saving its users an average of 30.7% on their initial mold costs . . . and on handling costs . . . due to its lower weight. And, most surprising to many users, every one has shown at least a 10% increase in mold life, up to a 47% increase at one plant producing special alloy steels.

Molds of this patented type owe their efficiency to many features. Primarily, the multi-taper contour of the big-end-up chamber contributes to homogeneity and soundness thru its quicker, uninterrupted progressive freezing of the ingot from bottom to top; and the shape of the mold walls contributes to approximately uniform cooling throughout the perimeter of the ingot. We should be very glad to give you details of results being obtained by present users, so that you can get an idea of their value in your own practice. Contact us or discuss the matter with your Basic Refractories Engineer, who represents us, on his next visit to you.

U. S. Patents:
2166587
2190116
2339601

The Gathmann Engineering Co., Baltimore 28, Maryland.

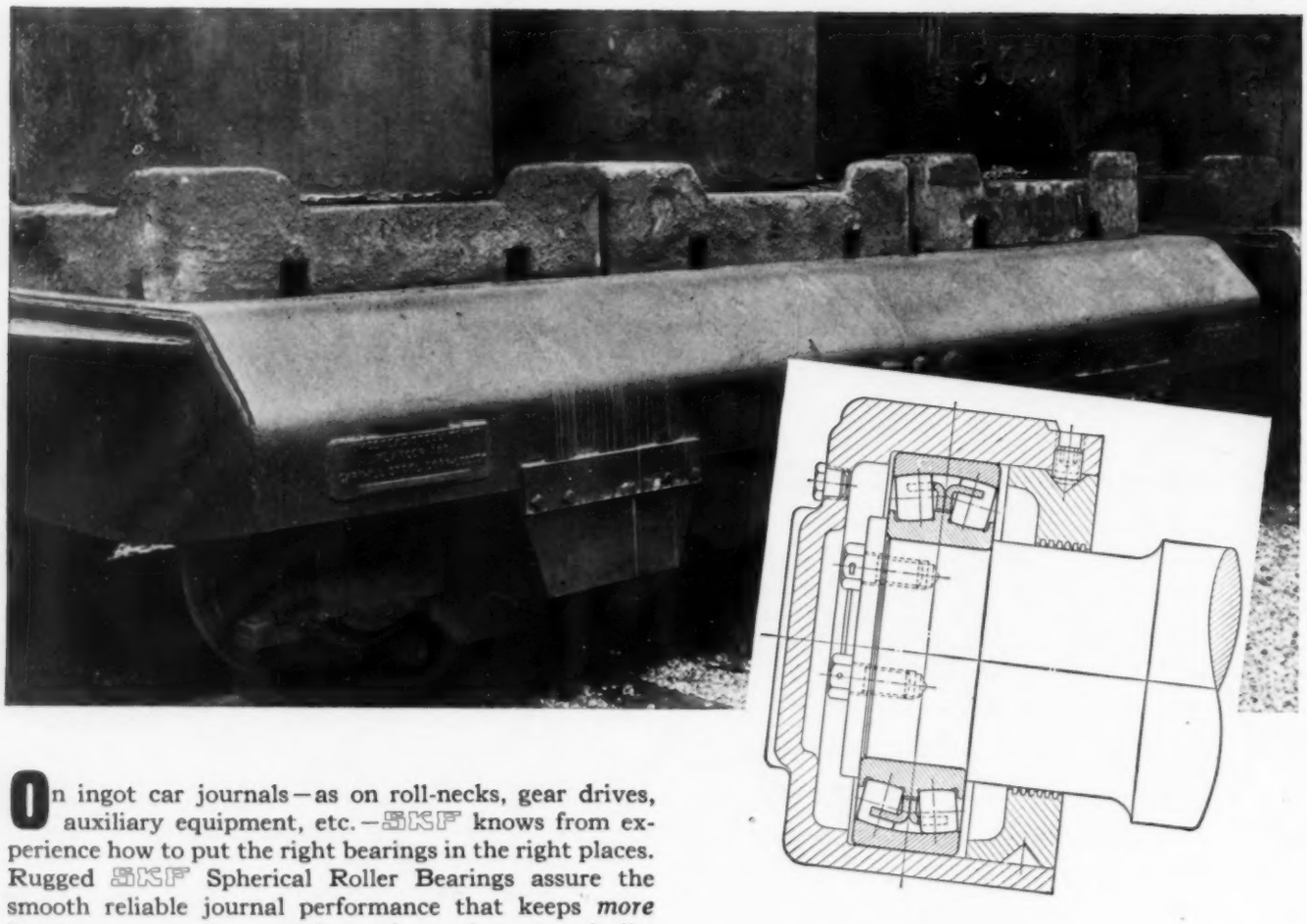
Under the heading "Taper in Ingots," beginning on page 82 of the second edition of Mr. Gathmann's book, THE INGOT PHASE OF STEEL PRODUCTION, you will find a complete discussion of ingot taper and clear explanation of the value of Gathmann patented multi-taper designs.

If you do not have this book, let us know and we'll send you a copy. Please write on your company letterhead.

**GATHMANN** *Multi-Taper*

SKF-ENGINEERED BEARINGS

# FOR INGOT CARS



On ingot car journals—as on roll-necks, gear drives, auxiliary equipment, etc.—SKF knows from experience how to put the right bearings in the right places. Rugged SKF Spherical Roller Bearings assure the smooth reliable journal performance that keeps *more* ingot cars moving *continuously* and *economically*. Their high radial and thrust capacity absorbs heavy shock loads resulting from track conditions. Their rolling alignment eliminates binding of the bearing. Their lubricant consumption is low. They need no adjustment. Add these advantages to dependable performance at low maintenance costs, and you'll know why so many vital moving parts in steel mill equipment depend upon SKF Bearings. 6492

SKF INDUSTRIES, INC., PHILADELPHIA 32, PA.

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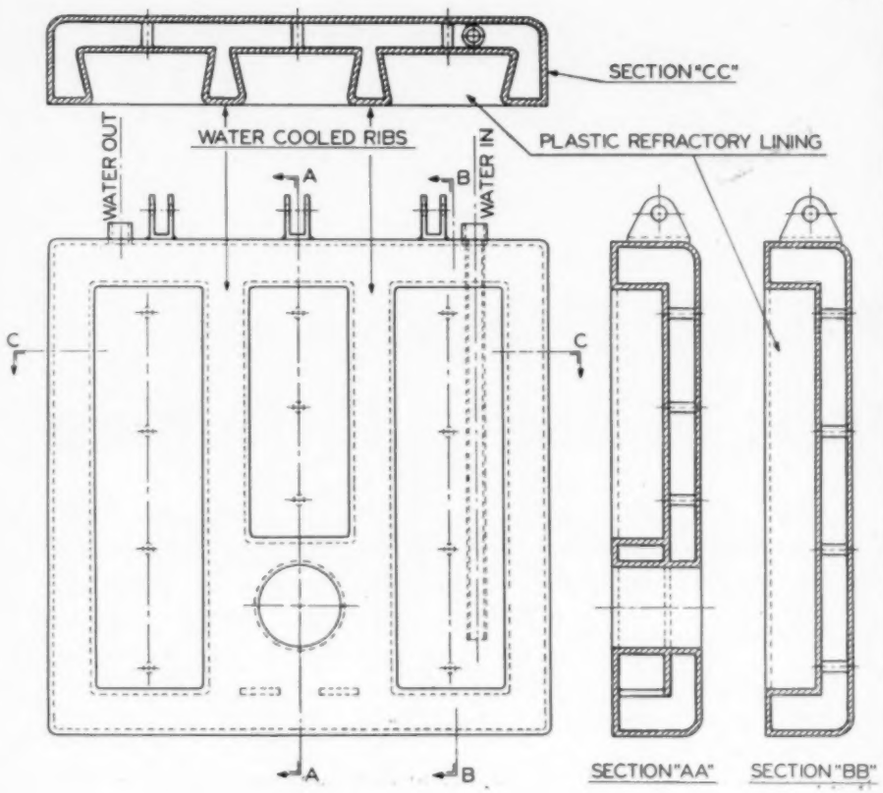
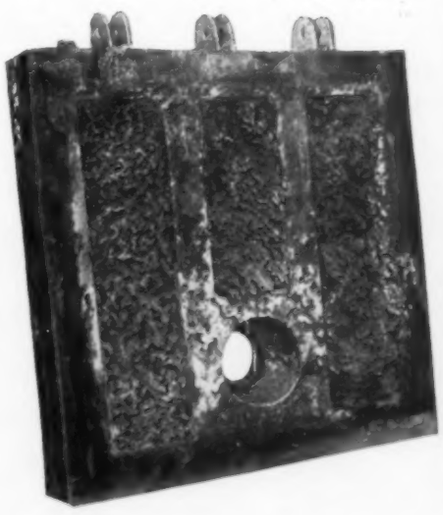
Patent Pending

# *Water Cooled Door*

## *for* OPEN HEARTH *and* HEATING FURNACES



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- **WATER-COOLED RIBS DIVIDE THE PLASTIC REFRACTORY INTO EASILY COOLED SECTIONS.**
- **GUARANTEED REFRACTORY RETENTION.**
- **ARRANGEMENT OF RIBS ADDS STRENGTH TO DOOR —ELIMINATES WARPAGE —ELIMINATES COSTLY STUDDING.**
- **DOORS CAN BE LINED WITH PLASTIC REFRACTORY BY UNSKILLED WORKMEN.**
- **LONGER LIFE FOR DOOR AND LINING—100 TO 300 HEATS PER LINING.**
- **DECREASED MAINTENANCE COST.**
- **PROVEN THROUGH SEVERAL YEARS OF ACTUAL OPERATION.**

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***Manufactured in all sizes of open hearth and heating furnace doors. Send us your door drawings for quotations.***

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GREFCO

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## GENERAL REFRACTORIES COMPANY

**Philadelphia, Pennsylvania**

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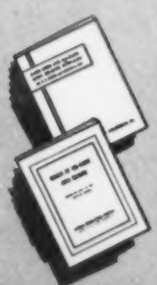

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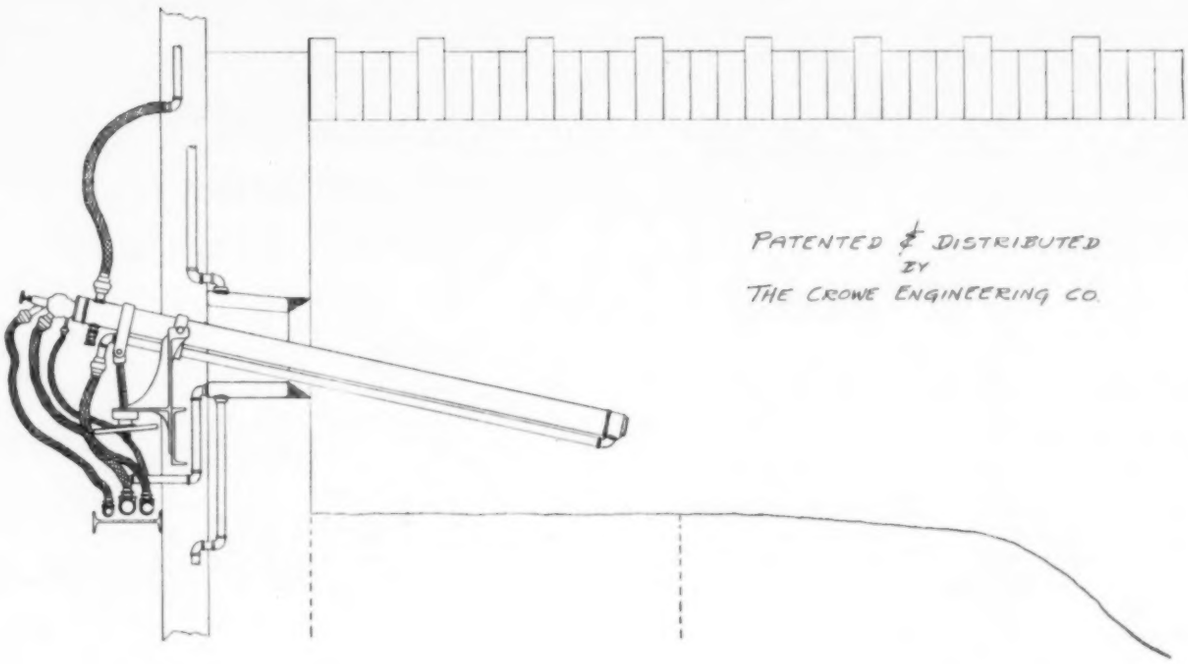
# *Artillery Type* WATER COOLED

# BURNERS

are paying dividends in Fuels and Time

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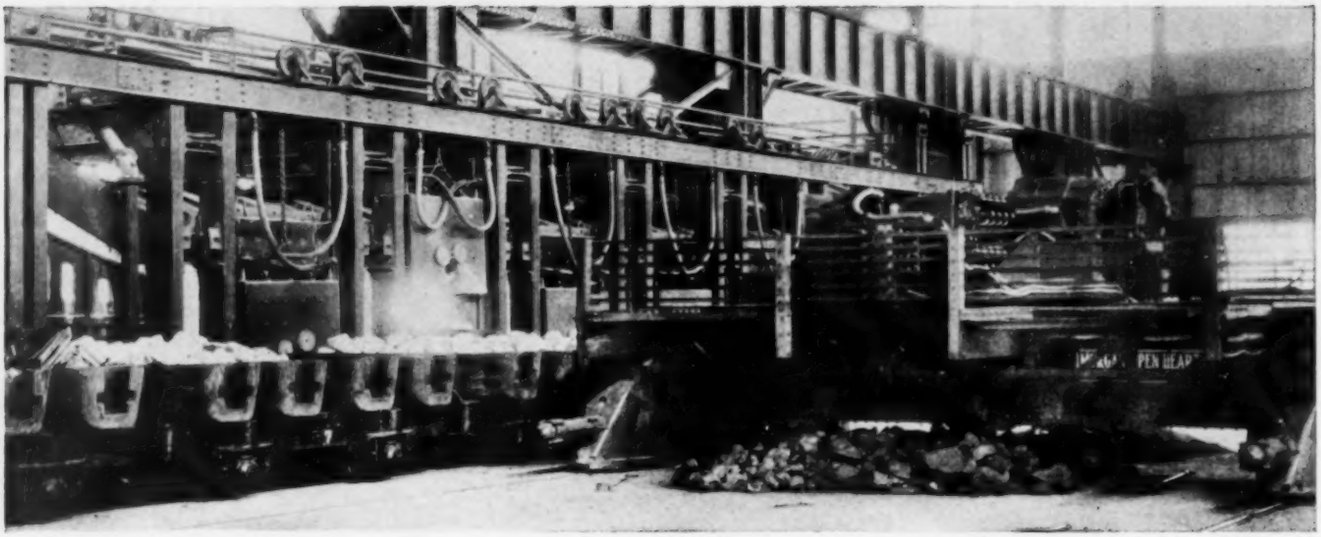


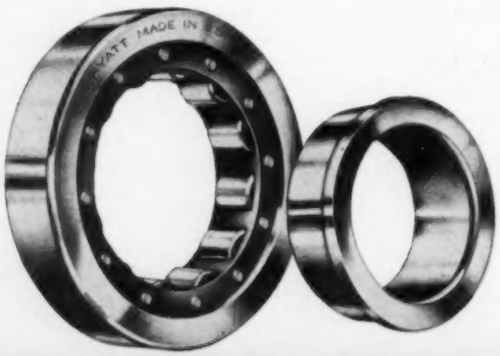
# IN OPEN HEARTH PLANTS

## *MORE THAN 90% OF THE INGOT AND CHARGING CARS OPERATE ON* HYATTS

**Over thirty years ago Hyatt engineers effectively demonstrated that more ingot mold and charging box cars could be handled by locomotives when the plain bearings were replaced by free-rolling Hyatts.**

**Since that time, advantages, other than power saving, have been proven by performance. The saving in maintenance of locomotives and car equipment alone amply repaid the initial cost of Hyatt bearings.**

**As a result, today more than 90% of the ingot and charging cars in open hearth plants are operating on dependable Hyatt bearings.**

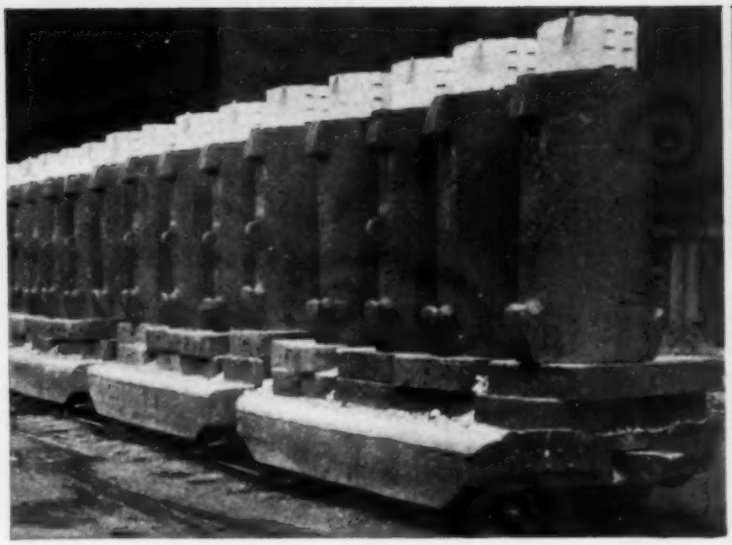


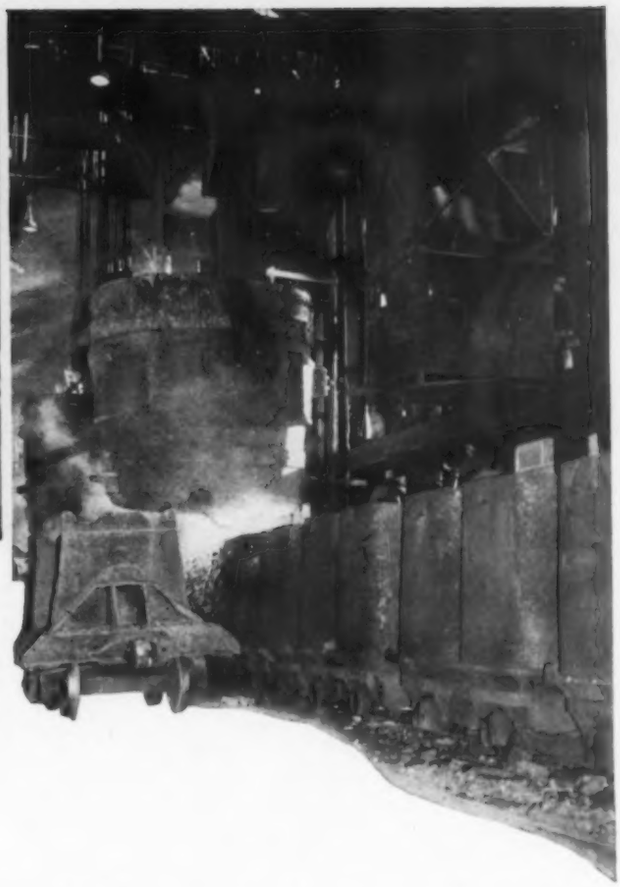
### *STEEL MEN PREFER HYATT BEARINGS*

### *Because:*

1. **Less tractive is effort required to move a trip of cars.**
2. **Cars can be handled more rapidly.**
3. **More cars can be hauled without an increase in power.**
4. **The cost of locomotive maintenance is reduced.**
5. **Wear is reduced and axle breakage virtually eliminated.**
6. **There is a minimum of bearing replacement.**
7. **Lubrication can be less frequent.**
8. **Less time is required for lubricating car bearings.**
9. **Production speed is increased from open hearth to stripper to soaking pits.**

**HYATT ROLLER BEARINGS**





# PROVEN MAINTENANCE SAVINGS ON LADLE CRANES, CHARGERS AND MILL MOTORS

Hyatt Roller Bearings throughout the majority of open hearth ladle cranes and charging machines help keep axles, shafts and gears in proper mesh and alignment. The result is smoother, quieter operation and reduced power and maintenance requirements.

The application of Hyatt Roller Bearings to ladle crane hook block sheaves has resulted in substantial savings in cable replacement and general maintenance. Free turning sheaves permit faster, easier handling and eliminate the fraying of cables.

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For further information write to Hyatt Bearings Division, General Motors Corporation, Harrison, New Jersey; Detroit, Chicago, Pittsburgh and Oakland, California.

**These builders of open hearth cars regularly supply Hyatt Bearings**

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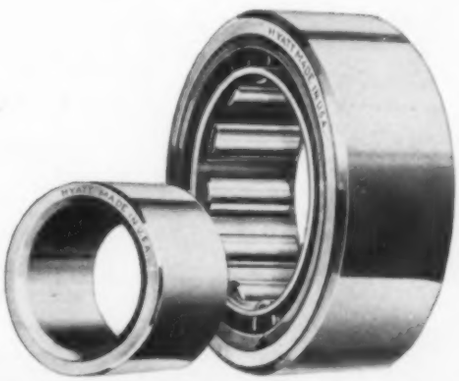
The William B. Pollock Company
Continental
Foundry & Machine Company
American Car & Foundry Company
Union Steel Casting Division,
Blaw-Knox Company

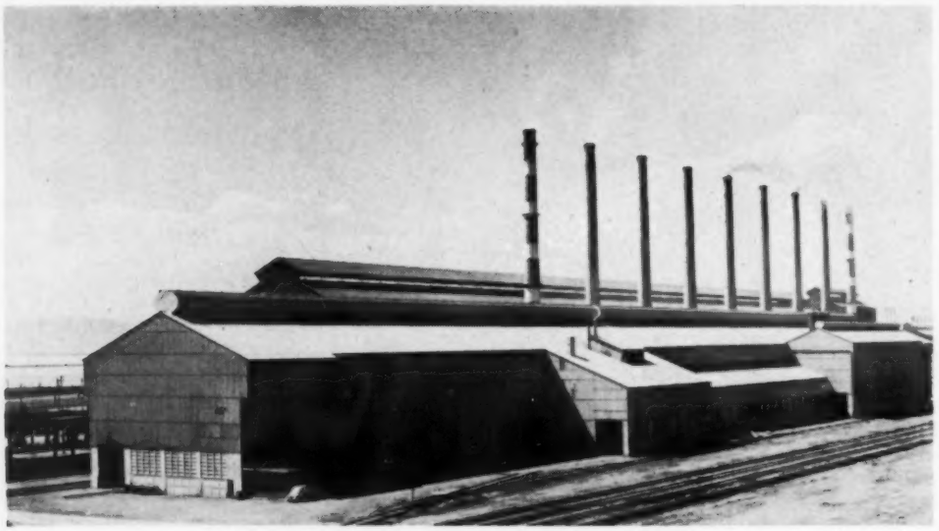


**HYATT ROLLER BEARINGS**

# Nine - 225 ton Open Hearth Furnaces

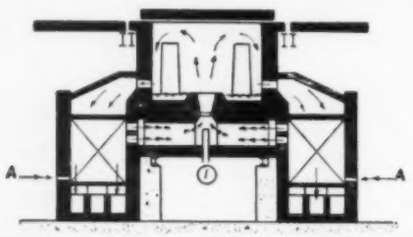
***built by***

# Amsler Morton Corporation

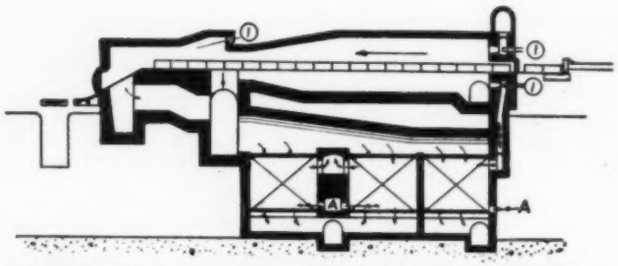


**Superior Service- *Means* Repeat Orders**

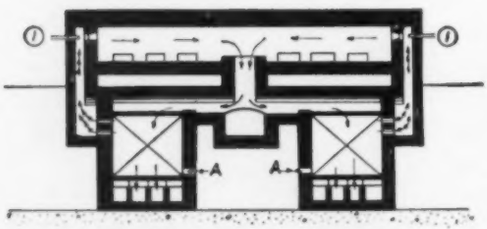
Described in The Saturday Evening Post, May 15, 1948




AMCO Vertically Fired Soaking Pit



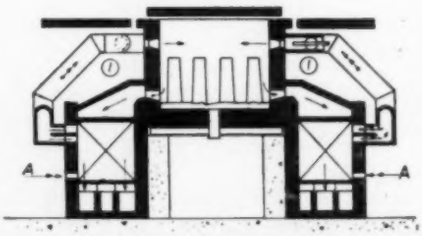

AMCO Continuous Slab Heating Furnace Fired from Charging End




AMCO Side Door Heating Furnace

SYMBOLS

Preheated Air
Pipe Burner
Amco Recuperator
Waste Gas
Cold Air
A




AMCO Horizontally Two Way Fired Soaking Pit

**AMSLER MORTON CORPORATION**

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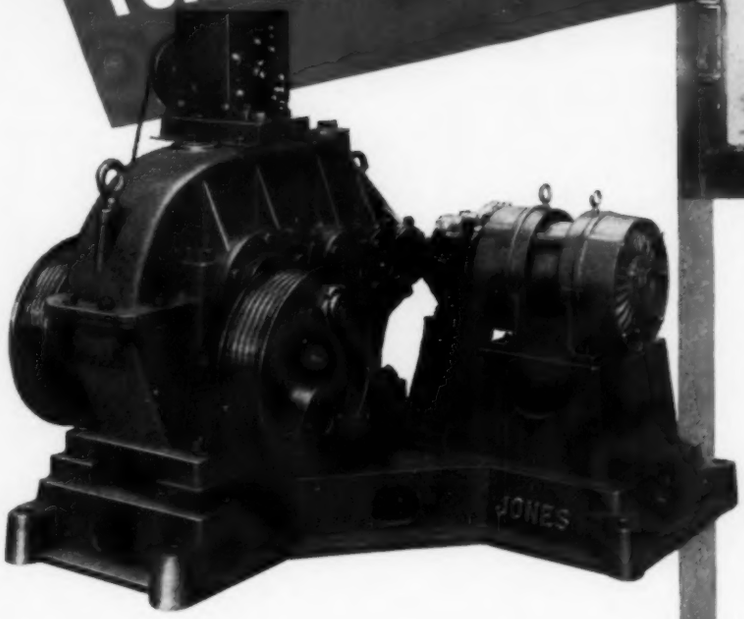
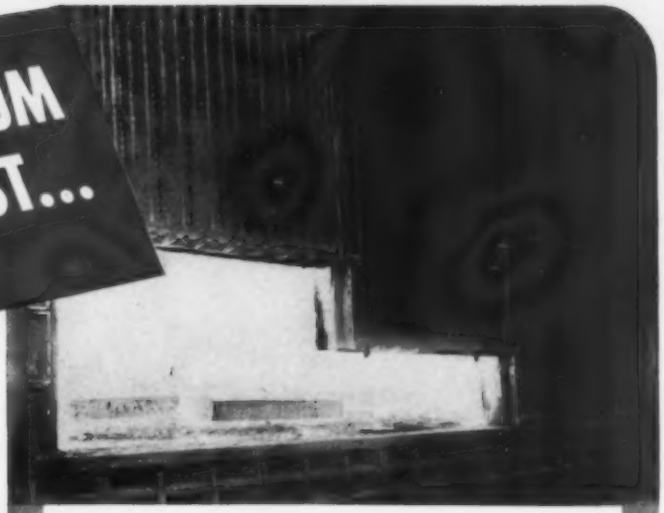
AM CORPORATION

# JONES ECCENTRIC DRUM FURNACE DOOR HOIST...





**JONES ECCENTRIC DRUM FURNACE DOOR HOIST** showing the two eccentric winding drums mounted on opposite ends of the slow speed shaft. Opening and closing take place on the short radius of the eccentric so minimum motor torque is required for starting. Furthermore there is practically zero impact when the door starts to open and when finally closing, as a protection to the refractory material. Electric brake is located between the motor and hoist and the limit switch is located on top of hoist. Speed reduction is through the Jones triple herringbone reducer unit.

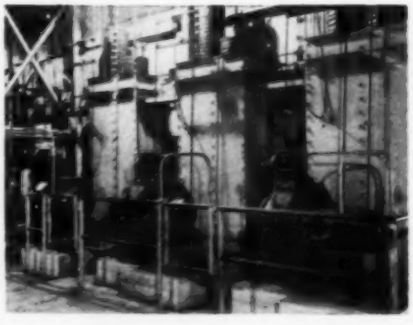
**THE JONES ECCENTRIC DRUM FURNACE DOOR HOIST** shown in the accompanying illustrations, was developed to handle the doors on **FRAZIER-SIMPLEX, INC.** "All-Door" Plate Mill Furnaces. Since each furnace, of the installation illustrated here, has six consecutive doors and no front wall and each door weighs 8500 lbs. (counter weighted about 6600 lbs.), it can easily be appreciated that the door hoists came in for the most careful engineering study. Three consecutive doors on each side of the divided furnace, provide an opening 21 ft. long in each furnace.

**THE JONES ECCENTRIC DRUM TYPE HOISTS**, developed to solve this door opening problem, have now been in operation several years and have provided the excellent service that has come to be taken for granted by the users of Jones transmission products.

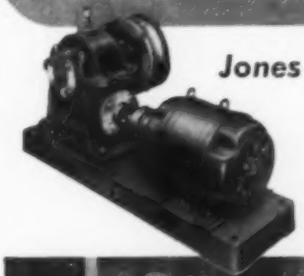
Door hoists of this, and other types, are built by Jones as complete units with motor included, if desired, or with a base to take standard motor as supplied by purchaser.

If you have a door handling problem, the Jones engineering department will be pleased to make a recommendation covering a unit for it.

**W. A. JONES FOUNDRY & MACHINE CO.**
**4431 Roosevelt Rd., Chicago 24, Ill.**



Rear view of the furnace showing three of the six Jones eccentric drum type furnace hoists and the door counter weights.



## *Jones "Slipper type" Hoists for small furnace or mill building doors.*

This Jones door hoist is built in several ratings and in almost any convenient arrangement of sheaves and cables. No limit switches of any kind are required with this unit. A bronze ring on the winding drum slips to take care of overwinding.

The two Jones door hoists shown at the left are installed for opening and closing mill building doors.

*Since 1890*

**Jones**

*In the Service of Industry*

**HERRINGBONE — WORM — SPUR — GEAR SPEED REDUCERS**
**PULLEYS • GEARS • V-BELT SHEAVES • ANTI-FRICTION**
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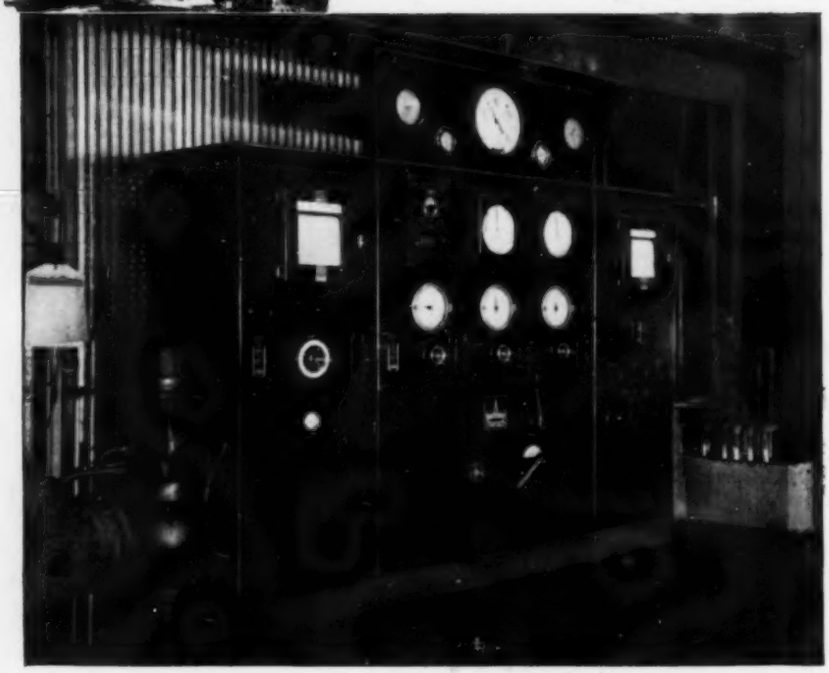
THE FINEST CONTROLS

*for steelmaking...*

# ASKANIA

## OPEN HEARTH CONTROL

★ ACCURATE
★ DEPENDABLE
★ SIMPLE
★ ECONOMICAL
★ STABLE
★ SENSITIVE



Askania offers the practical, efficient answer to open hearth furnace control. Askania Automatic Control provides constant heat input, combustion, furnace pressure and automatic reversal control to reduce a number of the variables in open hearth operation.

Typical Applications for Askania Controls for Open Hearth Operation:

1. Control to maintain uniform pressure throughout the furnace.
2. Control of heat input with single or multiple fuels.
3. Combustion Control for single fuel.
4. Combustion Control for multiple fuels.
   a. alternate fuels (either oil or gas).
   b. simultaneous fuels (oil and gas).
5. Automatic Reversal Control.

When considering control equipment for your plant get the facts on Askania Controls. Askania's staff of field engineers are available to work with you in solving your control problems.

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**SWINDELL-DRESSLER Corporation**

DESIGNERS AND BUILDERS OF MODERN INDUSTRIAL FURNACES

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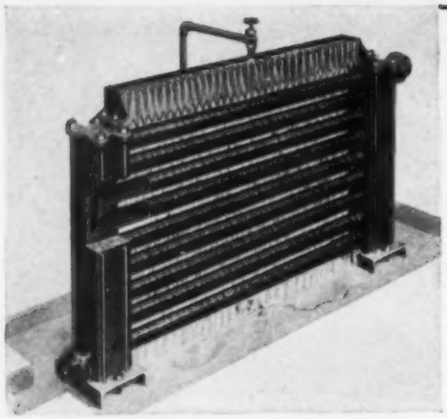
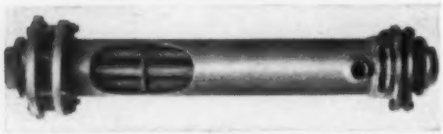
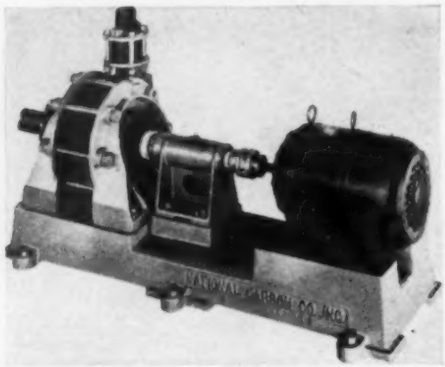


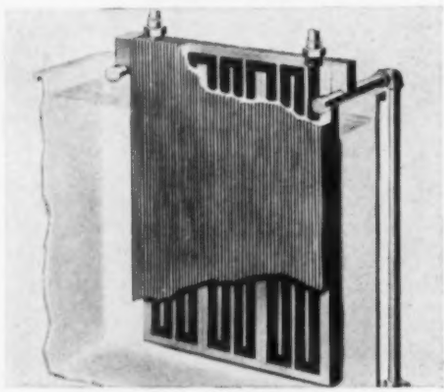
"Karbate" Sectional Cascade Cooler



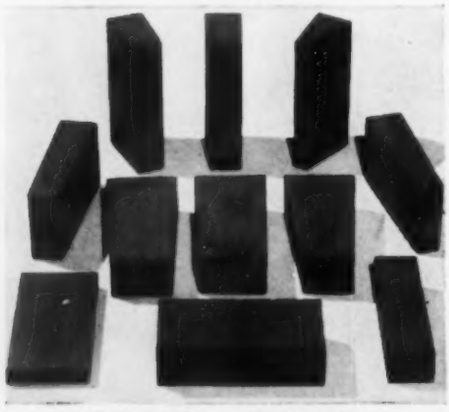
"Karbate" Series 70 Heat Exchanger



"Karbate" Pump



"Karbate" Plate Heater



Carbon Brick for Tank Lining

# How to lick corrosion if you pickle or plate metal . . .

# USE NATIONAL CARBON PRODUCTS

FOR HEATING, cooling, pumping, and conveying the corrosive solutions used in pickling and plating metal, there's no better equipment than that made of "Karbate" brand Impervious Graphite. This material is chemically inert, immune to thermal shock, easy to machine and install, light in weight yet strong; and has a very high heat-transfer rate.

Operating experience has proved that "Karbate" equipment stands up in sulphuric, hydrochloric, and nitric-hydrofluoric pickling solutions . . . Parkerizing and Bonderizing baths . . . nickel, copper, tin, and zinc plating solutions . . . electro-polishing and Alumilite and Alzak processes.

"National" carbon brick is now extensively used for lining tanks that handle corrosive solutions – particularly nitric-hydrofluoric.

For more details on metal-cleaning systems of standard "Karbate" brand Impervious Graphite units and "National" carbon brick, write to National Carbon Company, Inc., Dept. IS.

*These products sold in Canada by Canadian National Carbon Company Limited, Toronto 4*

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**NATIONAL CARBON COMPANY, INC.**

*Unit of Union Carbide and Carbon Corporation*

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# Clevelands

## IN THE MODERN OPEN HEARTH PLANT




FOR more than 30 years, Cleveland worm gear drives have been a familiar sight in the Open Hearth Departments of American steel mills. One of the earliest installations, back in 1917, called for 40 drives for the open hearth door lifters of an Ohio steel plant; one of the most recent comprised 98 units for the furnace doors of another Ohio plant.

Clevelands operate hot metal transfer cars, floor charger mechanisms, charging cranes, hot metal mixing cranes, open hearth door lifters, reversing valves, ladle cranes—in short, every type of moving mechanism that requires a dependable drive.

Wherever Clevelands serve—in the open hearth and in every other department—steel men know from long experience that they can depend on them for satisfactory, continuous service.

The Cleveland Worm & Gear Company, 3278 East 80th Street, Cleveland 4, Ohio.

*Affiliate: The Farval Corporation, Centralized Systems of Lubrication. In Canada: Peacock Brothers Limited*

**The complete Cleveland line includes standardized Worm Gear Speed Reducers in a variety of types and a wide range of speeds, ratios and power capacities. Special units are designed to meet unusual conditions. Our complete 150-page catalog, giving full information on all types, with specific engineering tables, furnished upon request.**

# FARVAL
## in the modern Open Hearth

FARVAL service in the Open Hearth Department dates back to 1928, when 8 systems were installed on hot metal mixer cranes and ladle cranes in one of the steel plants in the Chicago area.

Today, Farval centralized systems lubricate literally "everything that moves" in the Modern Open Hearth —hot metal mixers, charging cranes, floor chargers, furnace door sheaves, reversing valves, and ladle cranes.

In the open hearth, as well as in every other department of the steel mill, Farval provides dependable, continuous lubrication—saving oiling labor and lubricant, reducing maintenance expense, and contributing to uninterrupted production of steel through elimination of shutdowns and delays for bearing repair or replacement.

The Farval Corporation, 3278 East 80th Street, Cleveland 4, Ohio.

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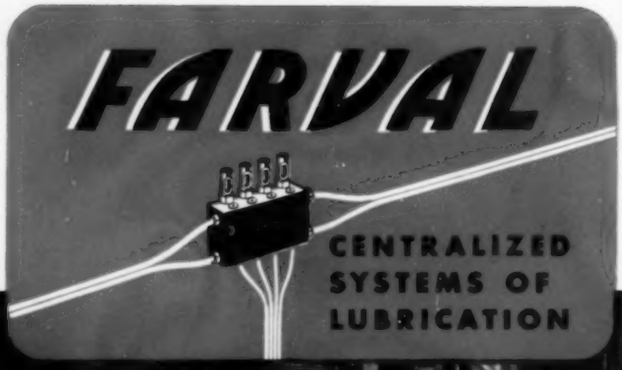
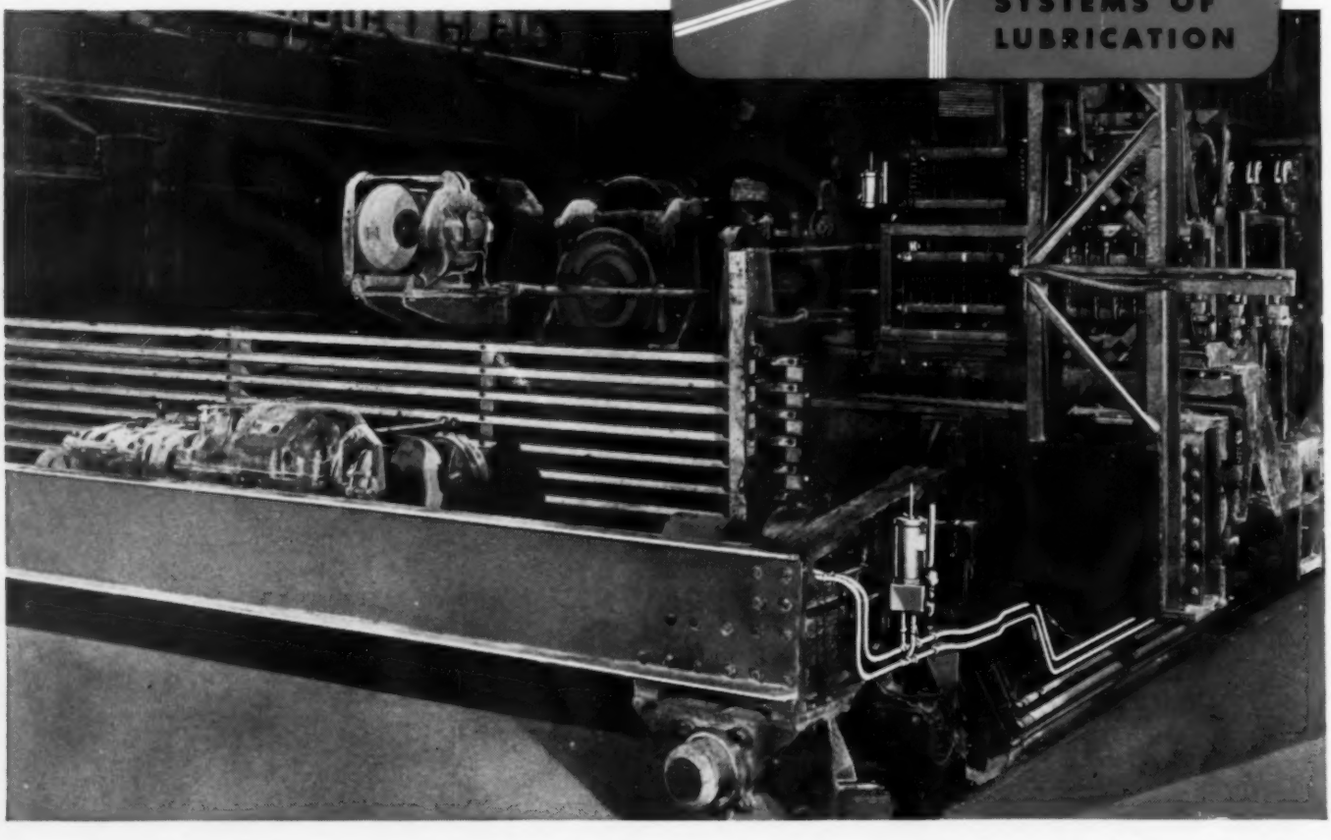


# Electrical Insulating Materials and Varnish

By B. F. McNAMARA
Vice President
Insulation Manufacturers Corporation
Chicago, Illinois

*. . . . thermosetting varnishes have several advantages over the conventional type: deeper drying, more infusible, and better bonding properties . . . .*

▲THE users of any electrically driven equipment, be it a motor, transformer or home appliance, rightfully expect dependable performance. A user is not concerned with what makes it operate, nor is he concerned with whether or not the operating conditions are good or bad. Electrically driven equipment means motion—motion means wear and wear necessitates maintenance, repair or replacement.

The responsibility of dependable performance is divided and rests upon many groups within our industry. A few of these groups are:

1. The design engineer.
2. The manufacturer of the equipment.
3. The manufacturer of the component parts, such as insulating materials, coils and so forth.
4. The maintenance and repair groups.
5. The distributor or contact group between the raw material manufacturer and the purchaser or user.

Each of these groups are dependent upon one another and should be familiar with their common problems. As nearly as possible they should operate from a common meeting ground.

This dependency of the groups noted within our industry applies also to the materials used in any piece of equipment. There is no one material that will do the necessary job; hence a combination of materials must be used. The efficient performance of equipment is dependent upon how well these materials work and how compatible they are with each other. The fact that a combination of materials must be used emphasizes an important fundamental, which is that every material has certain limitations or minus values. These minus values or limitations are not an indictment of the material; however, unless they are known and compensated for, serious difficulties can be encountered. It is imperative, therefore, that we learn as much as possible about the advantages and limitations of each material that makes up the combination.

The combination of materials used in any piece of equipment is referred to as an insulating system. An insulating system can be established only after the consideration of the following:

1. The assembly or the processing conditions to which the material is subjected.
2. The operating conditions.
3. The characteristics of a material, including the limitations as well as the advantages.

### 1. THE ASSEMBLY OR PROCESSING CONDITIONS TO WHICH THE MATERIAL IS SUBJECTED

Unfortunately in most instances the insulating materials are considered last. It is too frequently a question of what is obtainable to fit into a given space. The objective has always been to take as little space and have any piece of equipment as light in weight and as small as possible.

In one example, the individual laminations of any armature or stator have a severe cutting action on the insulation. Whether a coil is wound into a slot or whether a pre-formed coil is inserted, it is subjected to severe mechanical abuse, due to the necessary pounding and bending. The inserting of coils therefore results in many stresses and strains on the insulation. An insulating material may have excellent characteristics prior to its assembly but due to the necessary mechanical abuse the characteristics have materially decreased.

### 2. THE OPERATING CONDITIONS

Consideration must be given in the case of a motor to the centrifugal force or rpm, the vibration, the operating temperature, the frequency of stops and starts,

Presented before AISE Birmingham District Section Meeting, October 27, 1947

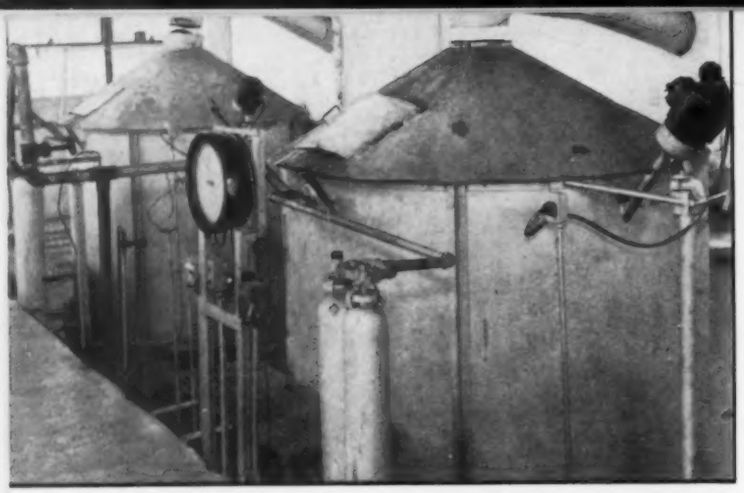


**Figure 1 — In these large processing units, extremely accurate control is used in manufacturing the varnishes.**

the atmospheric conditions in which the unit operates, the degree of overloading, and all of the circumstances that would influence the proper functioning and life of that unit.

### 3. CHARACTERISTICS — ADVANTAGES AND LIMITATIONS — OF A MATERIAL

The development of the best balanced electrical insulating system can be created only after all of the characteristics have been considered. By "balanced" and "all" is meant the mechanical, the chemical, the thermal and the electrical performance under the existing conditions encountered in the processing of it in equipment and under the many diversified operating conditions.

A "box score" similar to Table I should be used to evaluate each product, considering the factors mentioned:

It can be readily be seen that while our objective is "electrical protection", the means to that end requires thorough consideration and study. This Table I should enable one to rate each material and determine if a net advantage will exist.

### ELECTRICAL INSULATING VARNISH

Insulating varnish is a solution of either natural or synthetic gums or resins combined with oils and a volatile solvent or vehicle. The gums or resins and oils are referred to as the solids or non-volatile matter of a varnish and usually represent about 50 per cent of the solution. The remaining 50 per cent is the volatile matter or solvent which acts as the carrier of the solids.

There are different types of varnish, namely:

1. Air dry impregnating.
2. Spirit varnishes.
3. Sealer insulators.
4. Impregnating-baking.

While questions will be discussed on the other type varnishes, let us consider thoroughly the impregnating-baking type varnishes which are far superior in performance to any other type.

The two groups of impregnating-baking type varnishes are:

1. Conventional type.
2. Thermosetting-synthetic or polymerizing type.

The three outstanding characteristics of the thermosetting or synthetic type varnish and advantages over the conventional type are:

1. Ability to cure thoroughly; i.e., deep drying due to the heat reactive nature of the resins used.
2. They are practically infusible; i.e., will not soften under heat.
3. They are characterized by remarkable bonding properties.

The principal functions of insulating varnish are:

1. Provide an adequate internal and external mechanical bond which will prevent movement and abrasion of conductors from the common causes—magnetic and mechanical vibration.
2. Provide chemical protection against moisture, oil, acid, alkali, metallic particles, etc.
3. Increase the thermal conductivity of the windings.
4. Supplement the dielectric strength of the composite insulation.
5. To compensate for the deficiencies or limitations of the other materials in the system or combination.

The following characteristics should be considered in the selection of an insulating varnish:

1. Penetration.
2. Depth of drying.
3. Binding and adhesive properties.
4. High softening temperature.
5. Chemical stability or permanence.
6. Insulation resistance.
7. Waterproofness.
8. Oilproofness.
9. Alkali resistance.
10. Acid resistance.
11. Heat endurance.
12. Physical toughness.
13. Flexibility.

**TABLE I**

| Mechanical | Chemical | Thermal | Electrical |
|---|---|---|---|
| Tensile Strength | Resistance to moisture | Heat Conductivity | Insulation Resistance |
| Tear resistance | Resistance to acids | Resistance to low temperatures or cold | Power factor |
| Resistance to handling | Resistance to alkalies | Breathing | Dielectric strength |
| Ability to fold | Resistance to oils | Expansion and Contractions | |
| Flexibility | Resistance to gaseous vapors | Aging | |
| Elongation and stretch | Resistance to solvents | Overloads | |
| Compressibility | Resistance to greases | | |
| Shearing ability | Purity | | |
| Hardness, etc. | Corrosive tendencies | | |

TABLE II

| Mechanical | Chemical | Thermal | Electrical |
|---|---|---|---|
| Magnetic vibration<br>Mechanical vibration<br>Breathing<br>Starts — stops<br>Reversals<br>Centrifugal force | Moisture<br>Acids<br>Alkali<br>Dust, { magnetic / abrasion<br>Oil<br>Grease<br>Solvents | Heat conductivity<br>Aging<br>Overloads | Supplement dielectric of composite insulation in combination or system |

The above factors control the mechanical, chemical, thermal and electrical performance, as shown in Table II.

Insulating varnishes are formulated to cover a wide range of applications and, therefore, varnishes vary in each of the factors charted, i.e., mechanically, chemically, in their heat endurance, and electrically. The objective is to select a varnish having the best possible balance.

## PROCESSING CYCLE OR CORRECT USE OF VARNISH ON ELECTRICAL WINDINGS

Equal in importance to selecting the properly balanced varnish is the establishment of a process cycle which will permit the excellent properties of the varnish to serve the purpose intended.

The method employed to impregnate windings may vary but the primary steps consist of:

1. Pre-heating.
2. Maintaining varnish in proper balance (varnish condition).
3. Saturating or dipping.
4. Draining.
5. Baking.

We will consider each of these steps in detail.

*Pre-heating*—The advantages of pre-heating are:

1. Dissipation of moisture.
2. Expansion of conductors resulting in better penetration.
3. Reduction of curing cycle due to increased rate of solvent evaporation.
4. Possibilities of varnish "pockets" are reduced.
5. Healing of slight checks or cracks in Formvar enamel which may occur during winding process.
6. Air is inclined to shrink when units are immersed in cold varnish and results in "pulling" varnish more thoroughly into windings.

*Varnish condition*—The objective is to maintain the proper relationship or correct balance between the nonvolatiles (solids) and volatiles (solvents) at all times. This is accomplished by maintaining the solution at a uniform gravity, viscosity, and temperature. The solids used up should be replaced by fresh varnish and likewise the proper solvent must be added as needed. The rate of turnover of varnish is very important; therefore, a minimum size tank should be used.

It is advisable for the temperature of the varnish to be kept reasonably constant, not exceeding 95 F. This is controlled by consideration of the relationship of volume of varnish to the charge, and/or by equipping the tank with cooling coils. It is a good practice to observe the gravity and viscosity of the varnish at least twice a day, once before production starts and once about half through the run. Notwithstanding that heat thins varnish and could affect viscosity, gravity, build-up, and penetration by simple control methods, the many advantages of pre-heating can be realized.

*Saturation or dipping of windings* — The methods most commonly used to saturate the windings are:

1. Hot dip.
2. Vacuum impregnate.
3. Immersion—cold.
4. Brush or flow.

Varnish must have a path to its destination, and if that path is blocked by moisture, air, oil, grease, etc., the purpose of complete saturation will be defeated.

The units should be completely immersed in the varnish for the period of time necessary for thorough penetration. The period is most important and units should not be in any varnish longer than necessary. The period will vary based upon the wire covering, design of unit, type of insulation, etc. For example, the plain enameled wire assemblies will take up about half of the varnish in the first dip that a fabric-coated wire will. The pick-up of varnish in subsequent dips is about the same. Large units should be allowed to cool until the temperature is approximately 180 F. The units should remain submerged until the bubbling has ceased and immediately withdrawn.

*Draining*—The saturated windings should be removed at a slow uniform rate from the varnish and allowed to drain at room temperature. The objective is to remove excess varnish and prevent formation of "wet"

Figure 2 — A processing unit for synthetic insulating varnishes.

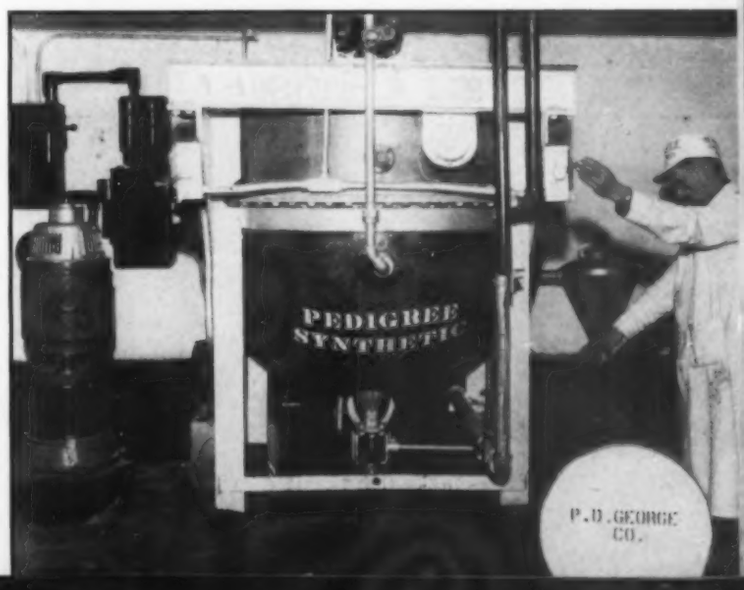


**Figure 3 — Another type of manufacture for processing smaller sized batches of varnishes, under extremely rigid control, for special applications.**

pockets and keep subsequent draining in the oven at a minimum.

The distribution of varnish after the capillary action of absorption is strictly mechanical. The uniform distribution of varnish results in maximum protection, better balance, which explains why many users reverse the units in a vertical position after dipping and draining but before placing in the oven.

*Baking*—This very important operation should be carried out in a well-ventilated oven with sufficient air changes to readily remove the solvent vapors. Curing is not effective until these gases are not only removed from the unit but also from the oven. The curing of varnish is the product of time and temperature, two variables that are dependent upon type of varnish, depth of windings, etc. The objective is to properly cure and polymerize the varnish in the deepest part of the winding but at the same time to prevent over-baking. Unfortunately in many instances ventilation of an oven and lack of control of baking temperatures are completely overlooked.

It will be found that the average baking temperature of the conventional type varnish is 250 F, and the baking temperature of the heat reactive type of thermosetting varnish is 275 F. The period of cure is in direct proportion to the temperature—that is, if the temperature is elevated, the curing period can be reduced. Likewise, if the temperature is decreased, it will lengthen the period. It is just as detrimental to overcure or "cook" a varnish as it is to undercure.

## SOLVENT DEFINITIONS

A solvent is a volatile liquid which dissolves another substance. It is a carrier of gums, resins and oils in varnishes.

The "table of properties of solvents" shows the boiling range, flash point, evaporation speed in minutes, kauri butanol value and the specific gravity.

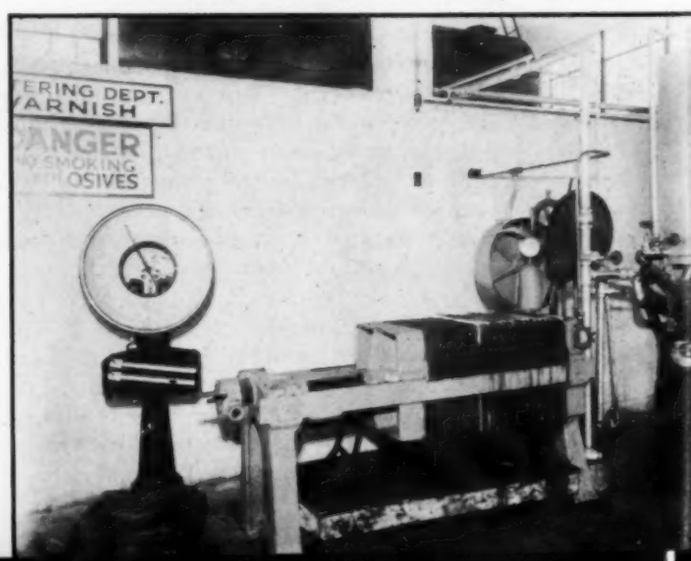
The boiling range of each solvent is determined with equipment and by methods established by A.S.T.M.

The flash point of a volatile liquid is the ignition temperature of its saturated vapor. All flash points are determined in a tag closed cup by A.S.T.M. methods. (Flash points determined in a closed cup are always lower than if an open cup is employed.)

Speed of evaporation is expressed in the table in terms of minutes required for 0.5 CC of a solvent to evaporate from filter paper. The published speeds are determined under identical conditions. However, such speeds will vary widely according to atmospheric conditions, temperature, humidity and barometric pressure. Therefore, the time required for evaporation should be used for comparison only.

The power of solvents for synthetic resins and gums is usually measured by a "dilution ratio" commonly referred to as kauri butanol. This term refers to the quantity by volume of the solvent under test which can be added to a solution of kauri gum in butyl alcohol before such solution just fails to be a solvent for the kauri gum. Kauri gum is soluble in the alcohols, but not in such liquids as toluol, oxylol, turpentine and petroleum naphthas. The paint and varnish production clubs have standardized a butyl alcohol solution of kauri gum for this test. It is so made that 20 grams of the solution will reach an end point when 105 CC of toluene are added. In this determination, 20 grams of the standardized solution are weighed into a flask. The solvent to be tested is then added until No. 10 print (ordinary newspaper print will answer) can be no longer be read when the print is placed under the flask. This is called the end point. The opacity of the solution is caused by the precipitation of the kauri gum. Examples. C. P. Hepthane is a highly refined petroleum naphtha containing no aromatics. It will produce an end point after the addition of 25.8 CC. Its K.B.V. is, therefore, 25.8. The K.B.V. of ordinary petroleum naphtha is 36.0; that of gum turpentine 64.5; Ennjay Solvent No. 1, 84.5; and xylol, 95.6. The kauri butanol value really measures the solvent powder of butyl alcohol for kauri gum in the presence of the liquid tested. In this light, the K.B.V. would have little value for butyl alcohol is not generally employed as the main solvent in any coating. The theory of the K.B.V. to the application of solvent power might be explained as follows: The synthetic resins and natural gums which are usually soluble in the alcohols, particularly butyl, are mostly insoluble in the coal tar naphthas. Conversely, most all synthetic resins

**Figure 4 — This filter press is one of a series through which these varnishes must be processed before shipping. This type of filter removes every semblance of foreign material and delivers the varnishes absolutely clean.**



employed in this industry are soluble in the coal tar naphthas, but insoluble in the alcohols. This is also true of certain natural gums. Let us assume that butyl alcohol represents the greatest solvent power of one type of solvent and toluol of the other. In between, you will find such solvents as petroleum naphtha and turpentine. Thus, a natural gum, which is completely soluble in butanol, may be slightly soluble in petroleum naphtha in the cold; only slightly soluble in turpentine, if heated, and completely insoluble in toluol. On the other hand, a certain synthetic resin may be completely soluble in toluol; slightly soluble in turpentine in the cold; slightly soluble in petroleum naphtha, if heated; and completely insoluble in butanol. Therefore, if toluol has a K.B.V. of 105, turpentine 64.5 and a petroleum naphtha 36, it is assumed that turpentine must be a proportionately better solvent than naphtha for a synthetic resin completely soluble in toluol.

Specific gravity is the ratio of the weight of a given volume of a liquid to the weight of an equal volume of distilled water, the comparison being made at a specified temperature. The specific gravity is important to the buyer when comparing costs of different liquids if they are sold by the pound. His finished product is sold by the gallon, and he, therefore, compares cost per gallon. To arrive at the weight per gallon of any liquid, multiply the weight of a gallon of water, 8.33 by the specific gravity of such liquid.

Viscosity is a measure of a solution's fluidity—its degree of thinness. It has nothing to do with specific gravity. Example: a particular alkyd (synthetic resin) may be very soluble in toluol, but with difficulty in a petroleum naphtha. Suppose that 10 pounds of the alkyd is dissolved in 10 pounds of toluol. The solution is very thin. Assume that the viscosity is tested by dropping a small ball bearing into a 15 inch cylinder filled with the solution. It touches the bottom in 5 seconds. Next, say 10 pounds of the alkyd is dissolved in 10 pounds of naphtha. For clarity, let us say that the naphtha has exactly the same specific gravity as the toluol. The solution is very thick because the naphtha is a poor solvent for this particular alkyd. Twenty seconds are required for the ball bearing to touch the bottom of the cylinder. Note that the solution made by dissolving the alkyd in toluol weighs exactly the same as that made by dissolving the alkyd in naphtha. (Both solutions weigh 30 pounds.) Both have the same volume, since we assumed the specific gravity of the toluol and naphtha to be the same. Therefore, because both solutions have the same weight and volume, their specific gravity must be identical. Nevertheless, one solution is four times as thick as the other based on the relative time required for the ball bearing to sink in each solution. Thick solutions are said to have high viscosities—thin solutions, low. The better the solvent, the lower will be the viscosity of the solution.

Our solvent chart is based on the use of a V.M.&P. naphtha and with the aid of a thermohydrometer makes it possible to predetermine how much solvent to add to a given volume of varnish to attain the desired specific gravity. This chart is based upon a temperature of 70 F and for each 10 F variation in temperature a 1 degree correction in Baume must be made. Example: 34 Be at 70 F, 33 Be at 60 F, 35 Be at 80 F.

## FACTORS IN USE OF COAL TAR SOLVENT VARNISHES ON ENAMELED WIRE

The factors which permit successful use of coal tar solvent varnishes on enameled wire are:

1. Type of wire used (conventional enamel, formvar, cotton covered, and so forth.)
2. Design of unit.
3. Varnish temperature.
4. Period of association of wire and solvent.

Solvents must necessarily be used in varnishes and vary in their cutting power and do affect enameled wire. They can be considered as necessary evils not only because the possibility of film attack exists, but because curing cannot take place until the solvent vapors are removed from the oven.

The most commonly used solvents are petroleum

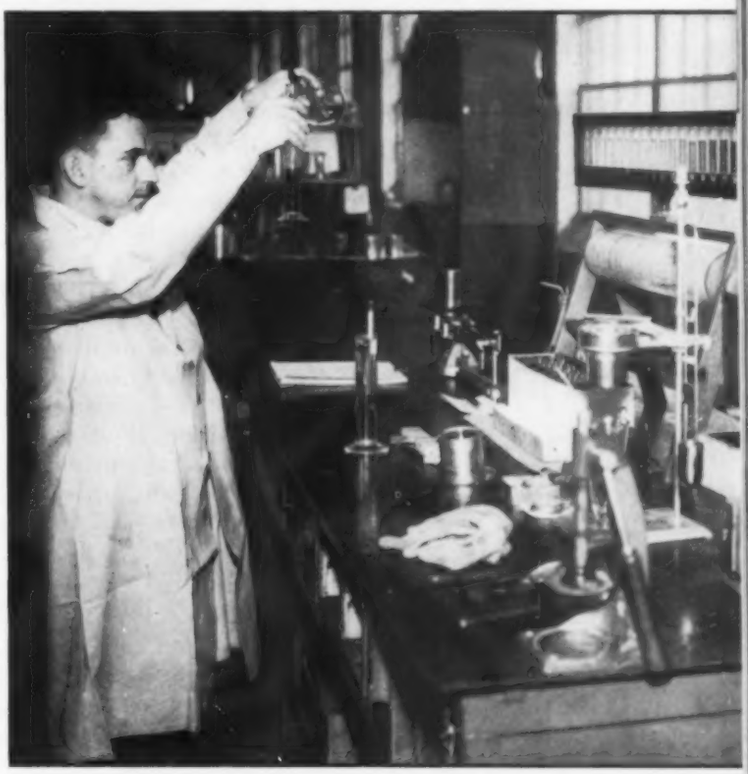


**Figure 5 — Technicians, with a wealth of experience, constantly check varnishes during manufacture. All finished varnishes must again pass rigid specifications and double inspection before shipment.**

such as V.M.&P. naphtha, mineral spirits; and coal tar solvents such as toluol, xylol, and so forth. The cutting power of petroleum solvents is considerably lower than the coal tars. They have an adequate cutting power to cut the gums and oils of conventional varnishes but do not have adequate cutting power for the heat reactive or synthetic type varnishes. It is for the latter group of varnishes that the coal tar solvents must be used. It is recognized that even V.M.&P. naphtha, under certain conditions, has a softening effect on conventional enamel and the finer the wire and the thinner the film thickness the greater the possibility of attack. The resistance to solvent of the formvar type enamel is many times greater than that of the conventional enamel. Recognizing the possibility of solvent action, therefore, we must aim to keep the period of association with the sol-

vent at a minimum. Each unit has a maximum volume capacity for varnish and, therefore, there is nothing to be gained by a longer period of immersion than is necessary. This period will vary with the type of wire, depth of unit, and design. As stated in the remarks on dipping, a bare enameled wire will only pick up half as much varnish in the same period of immersion as will a covered wire which we should be governed by.

The wire size and film thickness are influencing factors as obviously there would be a greater danger on fine, single enameled wire than there would be on the double or heavier thickness film. Particular consideration should be given to single enameled wire in sizes No. 30 and finer which does not mean that we should totally ignore the sizes between No. 30 and No. 20. The fact that the possibility of attack exists does not mean that the action will take place and harmful results obtained. It follows, too, that the varnish temperature would have a great bearing on the results. The higher the temperature the more active the solvent.

There is a difference between softening of enamel on wire and a separation of the film. The enamels, being thermo-plastic, are set up again as a result of the subsequent baking. We find from actual experience that on average size units when the minimum period of immersion has been established and the varnish temperature is within recognized limits that successful results are obtained.

*Instability of insulating varnish*—The instability of an insulating varnish means the approach of or the precipitation of the solids—i.e., gums or resins and oils. Contrary to the general opinion a properly formulated varnish does not require the attention of a scientist to maintain it in proper working condition. However, the attention to a varnish must be regular and constant and if a few necessary fundamentals are applied, the procedure is very simple and no difficulty should be encountered.

The difficulties which evidence themselves most frequently when a varnish is not properly taken care of are:

**Figure 6 — Special products for special applications are developed in the laboratory in small bottles before going into production. Constant research and continuous study make varnishes the most adaptable and foolproof finishes.**

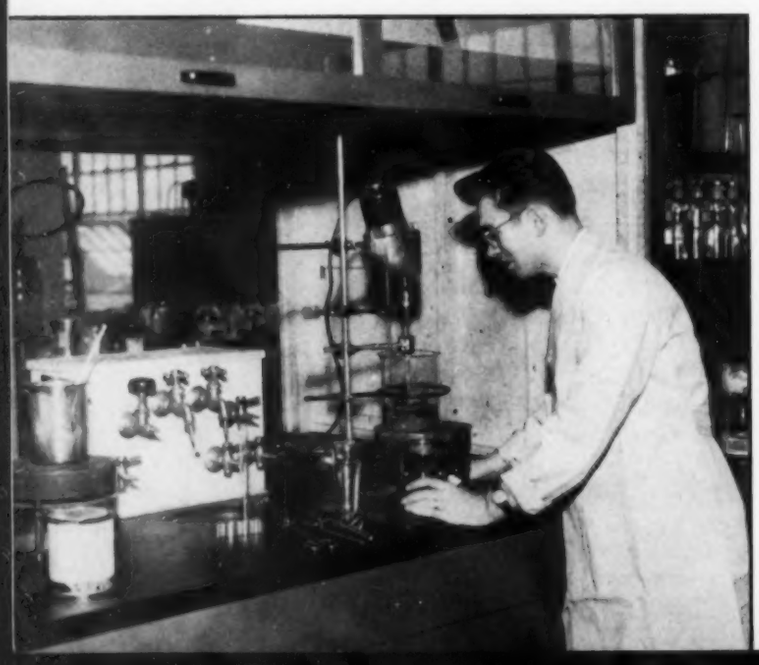


**Figure 7 — Impregnating unit for experimentation. Varnishes are tested in the laboratory under exactly the same conditions and processing as encountered in actual production.**

1. Livering.
2. Stringiness.
3. Precipitation of the solids.
4. Skinning.
5. Clouding.
6. Loss of viscosity due to excessive thinning.

These difficulties can be entirely eliminated if the operator is instructed to:

1. Maintain and check specific gravity twice a day.
2. Check viscosity.
3. Use the proper type and amount of solvent.
4. Introduce the solvent properly.

It is most important to use the solvent recommended by the manufacturer who knows the best solvent for his product. They do not sell solvents but are only interested in the correct one being used. The solvents which we use are alcohol, coal tar, petroleum and sometimes lacquer thinner and the properties and functions of each vary. It is entirely possible for a varnish that will tolerate petroleum thinner to eventually precipitate and throw out of the solution all of the solids because the particular petroleum thinner is not the recommended one.

*Freezing of varnish and solvent*—Lower temperatures cause a loss of solvency, particularly petroleum which in turn causes precipitation. A temperature of 30 F for example will produce livering. It is recommended that varnish should be stored at a temperature of from 60 F up to 100 F but not higher. Storage below the minimum temperature could produce precipitation and if the maximum temperature is exceeded the con-

dition might cause an increase in viscosity as well as skinning.

*Volume of varnish in tank versus consumption*—The more rapid the consumption of a varnish the better. All varnishes oxidize to a degree and when oxidation starts it becomes progressively worse and it is the exception when any of the recognized thinners will be effective. Oleoresinous varnishes contain a higher percentage of oils in most cases and this type is noticeably more susceptible to oxidization difficulties.

For example it would be impractical to have 100 gallons of varnish in a tank if the consumption was only 20 gallons a week. There are many influencing factors but a rule of thumb method is that exposed varnish in a tank should be turned over or used in about one week.

*Moisture*—Excessive amount of moisture invariably causes trouble due to reductions in dielectric strength, bubbling or pitting of the film during the baking. Too much moisture could emulsify the varnish and cause jelling or precipitation. Oil will absorb moisture faster than the gums or resins.

*Cleanliness of Tank*—The tank itself should be kept reasonably clean above and below the surface of the varnish. Varnish on the side of the tank oxidizes and due to the change in the level of the varnish, the varnish skin could be loosened and could fall into the varnish proper and contaminate it. During the constant procedure of dipping various type materials in the varnish, particles leave the units and settle in the bottom of the tank, contributing toward contamination. It is recommended that at least once a month the total contents of the tank be withdrawn and passed through a filter. The tank should be thoroughly cleaned of all objectionable material at this time.

## SEALERS AND INSULATORS

Protective sealers are made of a glyptol type base and are identical in every respect excepting color. These sealers provide the maximum protection against oil and water. See note on pigmentation.

Synthetic insulators are made of a phenol formaldehyde base and are identical in every respect excepting color. These insulators provide the maximum protection against alkalies and moisture. See note on pigmentation.

The above sealers and insulators are excellent in every respect for external protection. Depending on whether oil or alkalies must be the primary consideration, a choice of sealer or insulator can readily be made.

## PIGMENTATION OF SEALERS AND INSULATORS

These products are just like a paint in that they are pigmented (except the clears) and the pigment, being heavier than the vehicle, settles in the bottom of the container. It is imperative that these products are agitated before use. The amount of pigmentation varies with color. The clears do not have any, the blacks only 3 to 4 ounces per gallon and the reds about 2 to 6 pounds per gallon. The depth or degree of color varies with the amount of pigment, and the greater the amount of pigment the deeper the color. The lower the amount of pigment the easier to keep in solution.

A pigmented red is the only red that will maintain its color under heat. Red dyes sometimes introduced in varnish will not maintain their color and do not compare in build-up, flexibility, life or chemical resistance with a pigmented red.

**Figure 8 — This completely equipped laboratory rigidly follows the processing of electrical equipment. Baking is one of the most important processes in the use of insulating varnish.**

Some interesting figures are listed in Table III which can be used as a guide for recommending the proper consistencies:

**TABLE III**

| | Red | Black |
|---|---|---|
| Shipping — | | |
| Gravity | 1.1508 | 0.904 |
| Viscosity | 23 sec | 16 sec |
| Build-up | 0.0037 | 0.0035 |
| 25 per cent reduction — | | |
| Gravity | 1.1154 | 0.898 |
| Viscosity | 16 sec | 11 sec |
| Build-up | 0.0015 | 0.0015 |
| 50 per cent reduction — | | |
| Gravity | 1.0741 | 0.893 |
| Viscosity | 10 sec | 9.5 sec |
| Build-up | 0.0013 | 0.0009 |

It is our suggestion that while each application may have to be considered on its own, the following consistencies be suggested as a start in any application:

*Spraying*—Reduce the reds approximately 50 per cent; the blacks can be used as they are received for spraying or can be cut as the consumer desires.

*Dipping*—It is suggested that the reds be cut approximately 50 per cent and that the blacks be cut about 25 per cent.

*Brushing*—This is a matter of development, but a suggestion is that on the red it be cut about 30 per cent and the black about 15 per cent.

In a spraying operation a great deal of solvent is lost in the atmosphere which contributes to a faster drying curve. Toluol having an evaporation of 2.7 minutes is to be desired over any other solvent such as xylol, solcesso No. 2, etc.

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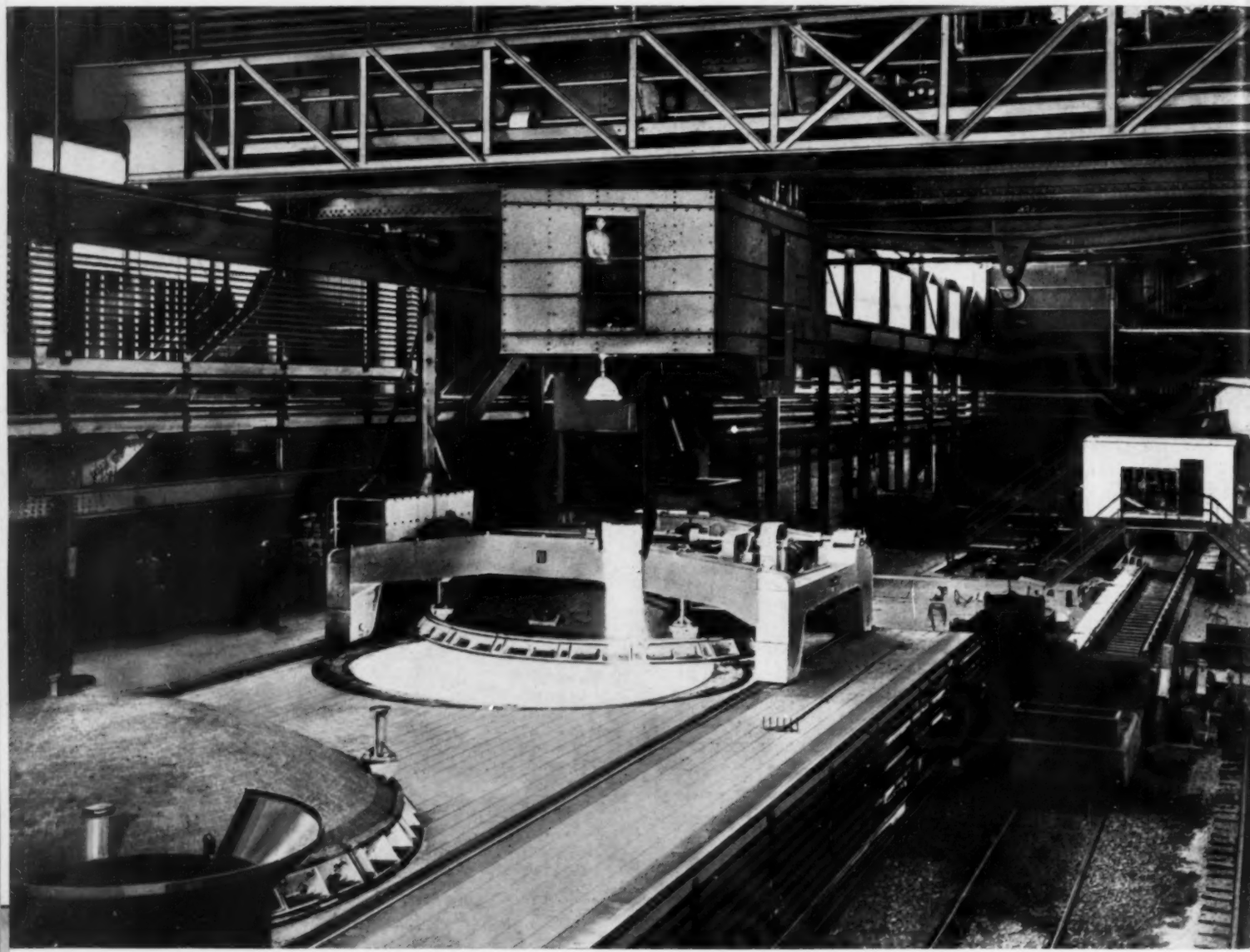
## MORGAN 7½-TON, 81′3″ SPAN SOAKING PIT CRANE



Illustrated is a Morgan 7½-Ton, 6-Motor, 81′3″ Span, Stiff Leg Type Soaking Pit Crane. It serves a Morgan 36″ Two-High Blooming Mill which was furnished complete with auxiliary equipment. It is equipped with fabricated welded trolley and bridge trucks. Morgan Pit Cranes are provided with spur or worm gear operated trolleys and sleeve or anti-friction bearings as required.

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## J & L'S ALIQUIPPA WORKS INCREASES CAPACITY BY USE OF THIRTEEN HOT METAL CARS

Installation of thirteen of the world's largest hot metal cars has increased iron producing capacity by 75,000 net tons per year at the Aliquippa works of Jones and Laughlin Steel Corporation. The new cars have a 200-ton capacity for molten metal, and have replaced old-style 25-ton open top ladle cars.

In a precedent breaking move, J & L is the first large steel producer to convert 100 per cent to the use of these monster "thermos bottles" for transporting molten iron from the blast furnaces to the bessemers where it is refined into steel. They also have eliminated two huge mixers at Aliquippa.

In the new system, molten iron from the blast furnaces will be tapped into the 200-ton hot metal cars, and carried to the bessemer converters. Here the hot metal will be reladled and poured into the bessemers to meet production requirements.

The old system was to tap the furnaces into the smaller ladles. The 25-ton ladles were then moved to the bessemer plant and emptied into one of two huge storage tanks or mixers.

In the mixers, the metal was kept in a molten state until needed by the bessemers. It was then poured from the mixer into a transfer ladle, which in turn was emptied into the bessemers as required.

M. H. Treadwell Company especially designed and built these cars which weigh 115 tons. Including the weight of fire brick lining and a capacity load of iron, the total weight is 368 tons. They are approximately 53 ft long from center to center of the couplings, and the height is approximately 13 ft.

The mixer type ladle car is so designed that the ladle remains in the trunions during all productive operations.

The hot metal is poured by means of an electric motor directly connected to a worm gear unit which transmits the power through a train of gears, the last of which is mounted on the trunion to revolve the ladle. The speed of the dumping mechanism is regulated to pour a maximum of seven tons per minute.

Trucks are of the conventional four wheel type, two at each end of the car to decrease the concentrated load on trackage. Cars are of heaviest construction to provide ample strength to withstand allowable impact from locomotives or other cars, as established by the Association of American Railroads.

Production advantages offered by these cars are derived from the design of the ladle, and elimination of excessive handling of iron.

The ladle consists of a horizontal cylindrical middle section with conical ends to which trunions are attached. The circular cross-section of the ladle offers the advantages of more uniform expansion of the lining which reduces spawling and abrasion, the minimum amount of lining material, as well as radiating surface per ton of metal capacity.

The tapered ends of the ladle tend to cause the kish or graphitic carbon released by the hot metal to accumulate at the ladle spout. This kish may

**The 13 new 200-ton hot metal cars have replaced old style 25-ton open top ladle cars, besides eliminating two mixers.**

One of the new cars is shown pouring molten iron into a smaller ladle.

be readily removed from the ladle after the iron has been poured. Thus, damage to the lining which commonly occurs in the old style open-top cars, is avoided.

Highest grade fire clay brick is used for lining the ladles. A lining life of 125,000 to 175,000 net tons is expected.


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Conservation of heat in the transportation of hot metal is one of the outstanding features of the new cars. The length of blast furnace runners is reduced, resulting in an average saving of 50 F in the temperature of the metal entering the ladle.

The loss of heat while the hot metal is in the mixer car depends upon the temperature of the ladle lining when the metal enters the ladle. From tests made by Treadwell, the average temperature of 180 net ton mixer car linings was 2050 F and in 75 net ton semi-closed top ladles was 1100 F. The new ladles at J & L are expected to exceed the temperature average for the 180 net ton cars.

After the lining becomes heated to the temperature of the metal, the loss of heat from metal in the mixer car averages 10 F per hour during the next 10-hour period. Loss in the open top ladle averages 55 F per hour during the first four hours, and approximately 35 F per hour thereafter.

It is estimated that these savings, plus the elimination of one reladling operation and omission of the old style mixers, will total an average of nearly 300 F from the blast furnace to the bessemers at Aliquippa. In this way the length of blow required at the bessemer will be reduced, and production speeded.

In addition to the conservation of heat by the mixer type car, other savings are anticipated as follows: The runner and ladle scrap which runs over seven per cent of total production of the old style open-top ladles, will be reduced to less than 1 per cent.

While using mixer type cars, the runner skulls and any scrap made at the pig machines is placed in the mixer type ladle and is remelted by the following cast, thus saving the cost of transportation, labor and metallic loss in preparing this scrap for remelting. The metallic loss when preparing scrap for remelting has been found to average three per cent of the scrap by actual test.

The quantity of runner sand and clay has been reduced at Aliquippa due to the shortening up of the total length of runner required.

Car maintenance, including the cost of lubrication, has been reduced due to the lesser number of truck journal boxes and other car parts requiring replacement.

The first mixer type ladle ever built was installed by the M. H. Treadwell Company at J & L's Pittsburgh works in 1916. That ladle was of 100-ton capacity, and the original car is still in use. Today, over 50 per cent of the total active production of hot metal in the United States is handled in mixer type cars.


**Use Product Information**
**SEE PAGE 19**


## FORT PITT BRIDGE ENTERS PIPE FABRICATION FIELD

Fort Pitt Bridge Works has entered the pipe fabrication field at its Canonsburg, Pennsylvania, works through utilization of a 36-ft press, powered with six 500-ton jacks, which was used to form bulkhead plates for oil tankers during the war. Another key operating unit in the fabrication of the pipe is a new welding mill.

The company already has shipped over 50,000 ft of 10¾ in. outside diameter pipe with ¼ in. wall and welded couplings, used for surface casing. This pipe does not have to be tested, although the company has tested short sections up to 2000 psi and is also testing 36-ft length sections intermittently up to 600 lb as they are being completed.

At present the company has capacity to fabricate about 250 ft of pipe an hour, and with some revamping of operating facilities officials state they can increase output about 400 ft per hour. This will be accomplished by installation of faster pumps on the press and extending the 36-ft press two feet on each end, thereby making possible the forming of a 40-ft length pipe. Increasing of the welding capacity also can be accomplished.

Officials state that by the Fort Pitt Bridge Works method of forming pipe, a press can be constructed so that it will form pipe one sheet to the ring for any diameter, length or thickness desired, being limited to the economical practicability of the diameter, length or thickness of pipe formed. The largest diameter pipe that can be formed on the company's present press as constructed is 10¾ in. outside diameter. However, pipe two feet in diameter and two feet long has been recently satisfactorily formed on a pilot press consisting of one frame.

Major production hurdle at the

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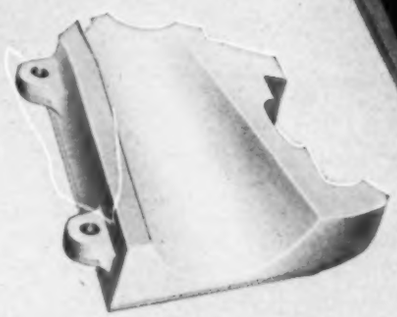

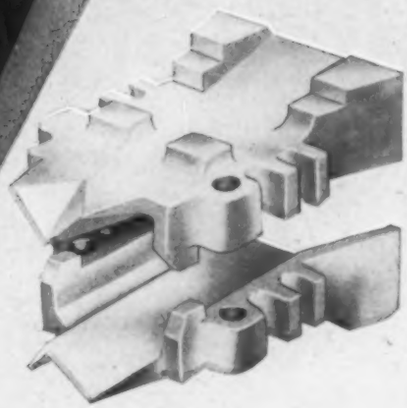

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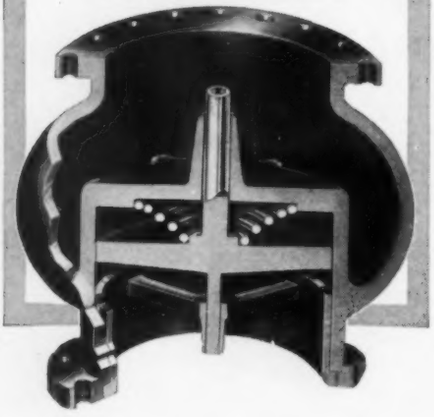

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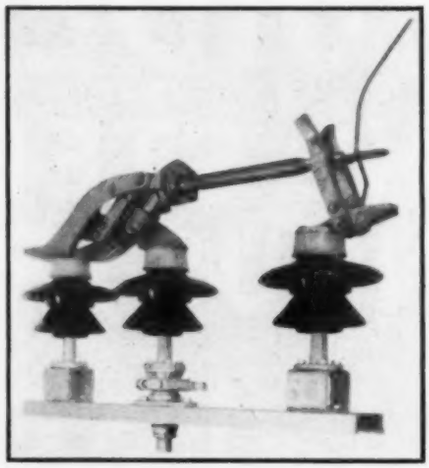
moment is acute scarcity of steel plates, officials state. Current inventory of plates is sufficient for but one 8-hour shift a day for a few weeks ahead.

## VERTICAL AIR SWITCH FOR HEAVY LOADS

A new vertical break air switch has been announced by the Delta-Star Electric Company.

Known as the "MK-40", this switch is of the rotating blade, high pressure contact type and is said to incorporate many new features highly desirable in the heavily loaded circuits of present-day power systems. Claimed for it are superior electrical and thermal characteristics emphasized by a minimum of current interchange surfaces, and simplified, positive mechanical design embodying a minimum number of parts.



**Superior electrical and thermal characteristics are claimed for this new switch.**

These new switches are available in all standard voltage and ampere ratings, for upright, inverted or vertical mounting.

## WATER SAVING SYSTEM INSURES ADEQUATE SUPPLY

A new $200,000 water conservation system began operating recently at Timken Roller Bearing Company to insure its plants the 7,200,000 gal of water they need daily for operation.

The system, consisting of a new two-acre, 10,000,000 gal reservoir and a 25 ft high, 60 ft long, and 30 ft wide cooling tower made of red wood on a concrete foundation, also saves more than 6,000,000 gal a day of local underground water supply.

Prompted by a deficiency in the rainfall since 1938 which, by 1945, had lowered the ground level in their 147 ft high, 12½ ft wide well, an additional 38 ft, Timken began construction of its reservoir and cooling tower early in 1947. Both were ready for operation by Monday, June 14.

Four thousand gallons of water, which flow by gravity from the melt shop furnaces through a concrete basin and pumped into the new tower are cooled each minute.

Part of the 10,000,000 gal of water in the reservoir comes from the rolling mills, where all cooling water flows by gravity to a pump house, which pumps it into the pool. From the pool it again flows by gravity back to the pump house and is returned to the rolling mills by another set of pumps.

## SKID HANDLING PROBLEM SOLVED WITH NEW TRUCK

The burden of handling live and semi-live skids has at last been shifted from human muscles to electric power. Such skids can now be handled through modern, mechanized methods by a special modern Transtractor developed by Automatic Transportation Company.

The first and only successful motorized unit built for this purpose, the truck ushers in a virtual horse-and-buggy-to-automobile transition for users of live and semi-live skids. Making the new unit workable where previous similar attempts have failed, the designers of the new unit have solved the problems of providing: (1) Full driving traction when lifting heavy loads; (2) Maneuverability virtually equal to that of a hand lift jack; and (3) Capacity to handle skid loads of literally any size.

The unit is built around the chassis and driving unit used on Automatic's famed Transporter motorized platform and pallet trucks and the Transtractor push-pull unit. Trailing wheels and lifting arm are mounted on a specially-designed rear-end frame, which is the core of the unit's operation.

The lifting arm is slightly forward

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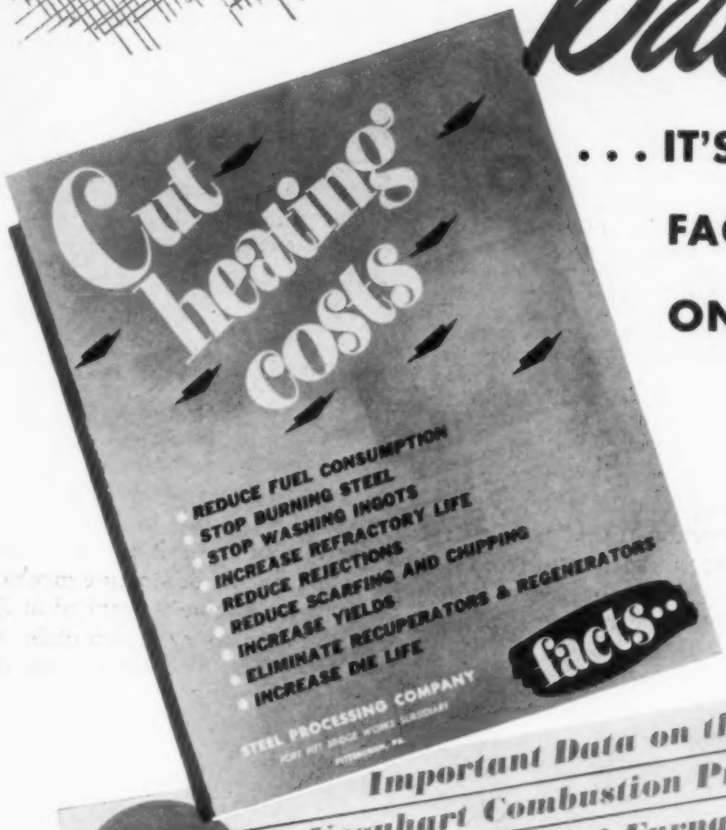

Important Data on the
Urquhart Combustion Process
for Industrial Furnaces
HOW THE PROCESS FUNCTIONS
FORGE FURNACE APPLICATION
SOAKING PIT APPLICATION
URQUHART PROCESS CAN BE APPLIED TO YOUR PRESENT FURNACES WITH MINIMUM CHANGES

Just off the press—the most factual information available on the Urquhart Combustion Process—giving actual case histories and the things you'd like to know. Write today for your free copy.

**STEEL PROCESSING COMPANY**

*FORT PITT BRIDGE WORKS SUBSIDIARY*

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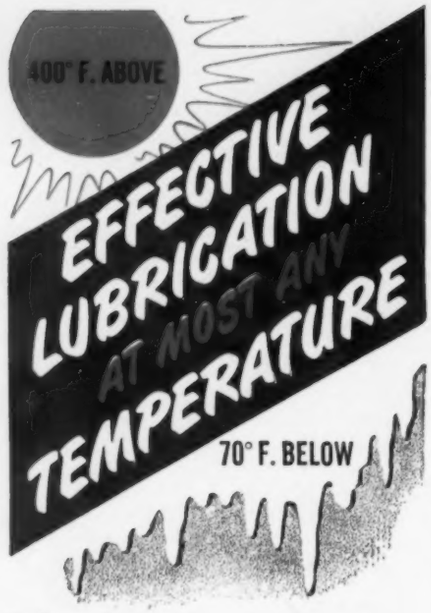



The fact that LUBRIPLATE Lubricants are able to meet extreme temperature conditions, demonstrates the ability of these products to cope with the wide variations often found in everyday industry. Besides this feature LUBRIPLATE Lubricants possess attributes not found in conventional lubricants. Write for literature.

**LUBRIPLATE**

Lubricants definitely reduce friction and wear to a minimum. They lower power costs and prolong the life of equipment to an infinitely greater degree. LUBRIPLATE arrests progressive wear.

**LUBRIPLATE**

Lubricants protect machine parts against the destructive action of rust and corrosion. This feature alone puts LUBRIPLATE far out in front of conventional lubricants.

**LUBRIPLATE**

Lubricants are extremely economical for reason that they possess very long life and "stay-put" properties. A little LUBRIPLATE goes a long way.

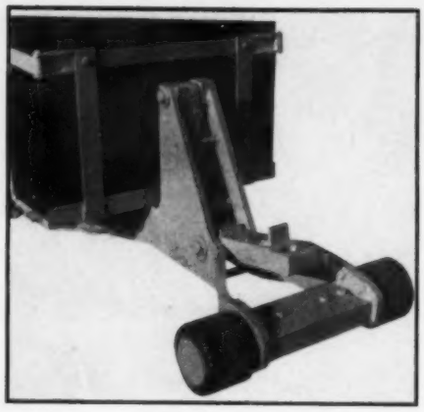
LUBRIPLATE

FISKE BROTHERS REFINING CO.

NEWARK 5, N. J. TOLEDO 5, OHIO

DEALERS FROM COAST TO COAST

CONSULT YOUR CLASSIFIED TELEPHONE BOOK



**Lifting arm on the new live and semi-live skid electric powered Transtractor is positioned slightly forward of the trailing wheels. This provides full traction when a heavy skid load is lifted — a 4000-lb load, for instance, adds 60 lb traction to the drive wheel. The specially designed rear-end frame, on which the trailing wheels and lifting arm are mounted, is the core of the new unit.**

of the trailing wheels, which are so built and positioned that they enter beneath either a live or semi-live skid between the skid legs or wheels. Positioning of the lifting arm ahead of the trailing wheels provides full traction when a heavy skid load is lifted—a 4000-lb load, for example, actually adds 60 lb traction to the drive wheel.

Position of the trailing wheels, meanwhile, together with the design of the frame permits the unit to jackknife virtually to a 90-degree angle, providing maximum maneuverability.

Both lifting arm and trailing wheel assembly are built to the specifications of the skids to be handled. Length of the trailing frame assembly, for example, is determined by the width of the skid to be handled, in order to assure maximum maneuverability.

The new truck is equipped with the Automatic dual lift, a new foot pump recently announced as a feature of Automatic's new 1948 line of Transporters. This pump reduces by an average of one-third the foot pressure necessary to lift loads into moving position. It combines a low pressure (high speed) hydraulic cylinder for raising the lifting arm into contact with the skid and a high pressure (low speed) cylinder for raising the load.

The ATCO electric lift, the only electric lift so efficient that a truck equipped with it can operate on a standard 11-plate battery, is available at the buyer's option.

Design of the new unit includes all of the features built into Automatic's regular motorized hand truck line. These include complete "dead man control," double-position brake applied by either raising or lowering the guide handle, new enlarged bumper guard providing full "protective clearance" around vital working mechanisms, easy accessibility of all parts within the drive unit and lifting mechanism, and simplified arrangement of all controls so that they may be operated virtually simultaneously and with one hand, except on dual lift models where foot pressure is used for lifting.

## AIR MOTORS FOR USE AS ENGINE STARTERS

Ingersoll-Rand Company is now producing air motors of two sizes as starters for internal combustion engines. The air motor is keyed or splined to the Bendix or starting mechanism and the engine is cranked in the same manner as an automobile engine is turned over when using the electric starter.

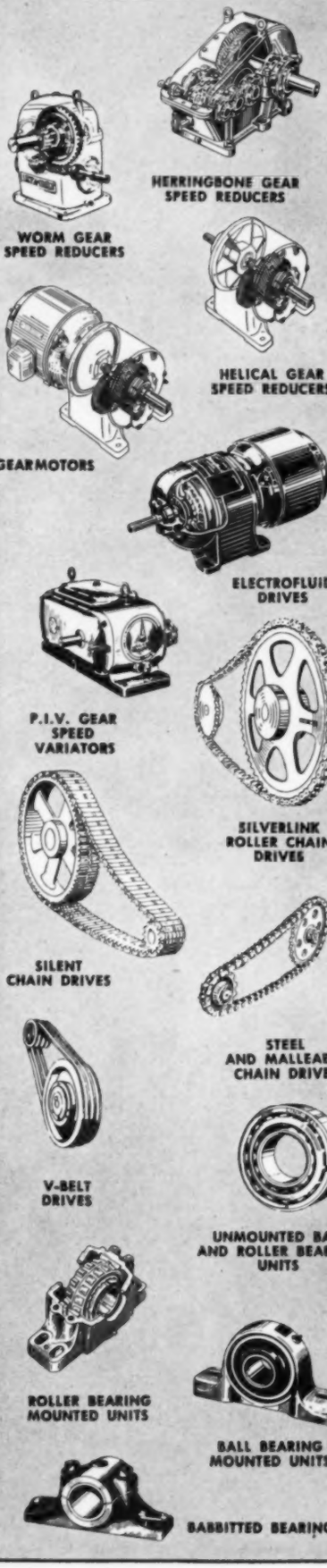
The starting motors are known as the size 9BM and size 20BM; the former having 9 hp and the latter 20 hp at 90 psi air pressure. They are small and compact having an overall length of only $13\frac{3}{16}$ in. and $14\frac{1}{2}$ in. The air motor is of the "Multi-Vane" type and the throttle valve is of the quick opening type to give peak horsepower almost immediately. A single step spur gearing is used to obtain suitable speeds.

## REPUBLIC TO BUILD 38 NEW COKE OVENS

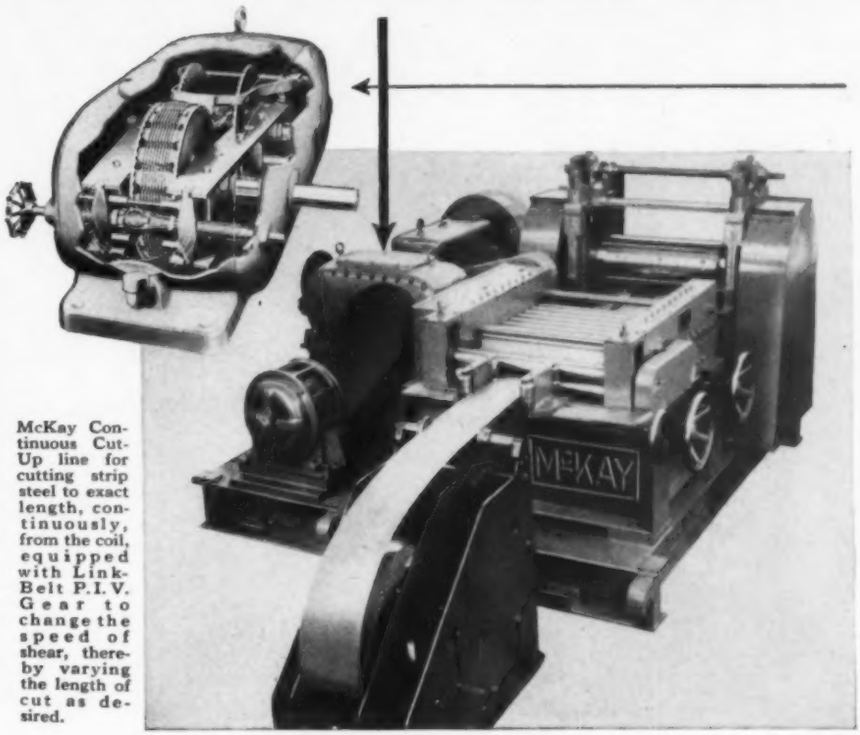
A new battery of 38 coke ovens will be built at Republic Steel Corporation's Youngstown district steel plant, it was announced recently. The new coke ovens will be built adjacent to the present coke plant which is located near the Mahoning River, east of the Central Street bridge.

The construction is part of a general modernization and improvement program which Republic has undertaken at the Youngstown plant. The installation of high top pressure blast furnace blowing equipment on three

**OTHER TYPES OF LINK-BELT POWER TRANSMISSION MACHINERY**




# SELECT---*and Maintain* YOUR IDEAL MACHINE SPEED WITH P.I.V. GEAR *Speed Variator!*




McKay Continuous Cut-Up line for cutting strip steel to exact length, continuously, from the coil, equipped with Link-Belt P.I.V. Gear to change the speed of shear, thereby varying the length of cut as desired.

Wherever precise speed is a factor in any manufacturing process, the unique P.I.V. Gear speed variator gives outstanding satisfaction.

With this unit, power is transmitted positively through an all-metal chain, making tooth-to-tooth contact with metal wheels. Speeds can be varied infinitely within range of the unit and once selected, the chosen speed is maintained accurately. Speed is changed while the drive is running, by a small hand wheel or by automatic or remote control.

For precise speed control in any type of industrial application use the P.I.V. Gear. Built in a wide range of sizes, and types, fully described in Book 1874.

**LINK-BELT COMPANY**

Chicago 9, Indianapolis 6, Philadelphia 40, Atlanta, Dallas 1, Minneapolis 5, San Francisco 24, Los Angeles 33, Seattle 4, Toronto 8.

11,004 Offices, Factory Branch Stores and Distributors in Principal Cities.

**LINK-BELT**

THE SYMBOL OF QUALITY — LB — LINK-BELT

**Power Transmission Machinery**

of the five blast furnaces and the improvement of the plate mill which permit production of hot rolled strip steel are other phases of this program now completed or under way.

When the new coke oven battery is ready for production some of the oldest existing ovens will be dismantled. The overall coke production of Republic's Youngstown plant will thus not be greatly increased.

Construction of the new battery will be undertaken by the Koppers Company and the work will begin later this month. The battery will be in production in June 1949.

These ovens will be arranged in a single battery designed for coke oven gas under firing. They will carbonize 878 tons of coal per day when operating at 17 hours coking time and based on coal at 50 lb per cu ft. They will be equipped with self-sealing doors and the contract will include a larry car, pusher, coke guide, door machine, and miscellaneous equipment.

The oven walls will be of Koppers' patented hammerhead rectangular construction of the saddle type design with vertical flues. No additions are contemplated for the by-product or benzol equipment.

Republic is currently building two new batteries of 40 ovens each at the Warren district plant. These two new batteries will replace 64 old ovens, 17 of which have already been torn down. When the first battery of 40 ovens is completed, the remaining 47 will be torn down to make way for the second battery.

In addition, Republic has made arrangements to purchase the RFC battery of 61 ovens in Warren and will continue to operate these.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AMERICAN CHEMICAL PAINT COMPANY
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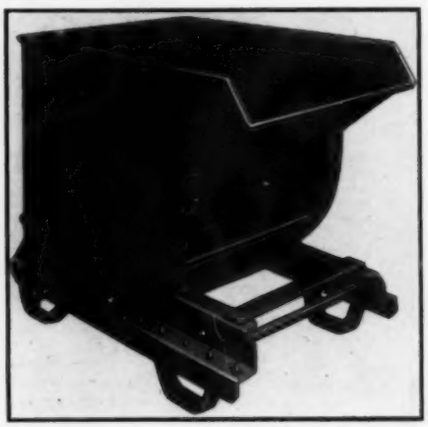
## SKID DUMP UNIT IS IMMEDIATELY AVAILABLE

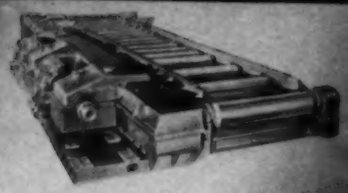
Heavy loads of scrap, castings and other industrial materials, are hauled and dumped efficiently and economically with the improved Model MF-1 "Skid Dump." Immediately available from Phillips Mine and Mill Supply Company, this dumping unit is easily handled with either platform or fork lift trucks. Capacity of this dump truck is 24.1 cu ft or .9 cu yd, full; with a 6 in. surcharge, capacity is 30.25 cu ft or 1.11 cu yd. Constructed for rigorous and long-time service, the hopper is fabricated of sturdy $\frac{3}{16}$ in. steel plate, with smooth rolled edges. Greater strength and durability are also supplied by formed channel legs and heavy duty welded undercarriage.

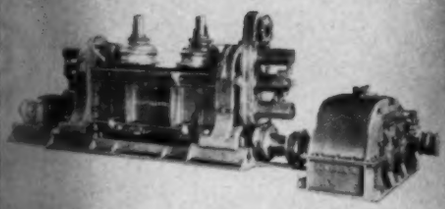


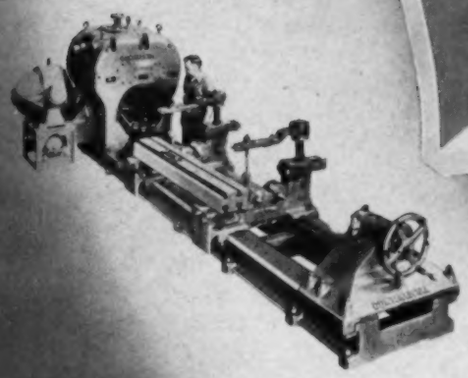
**This skid dump unit is easily handled with either platform or fork lift trucks.**

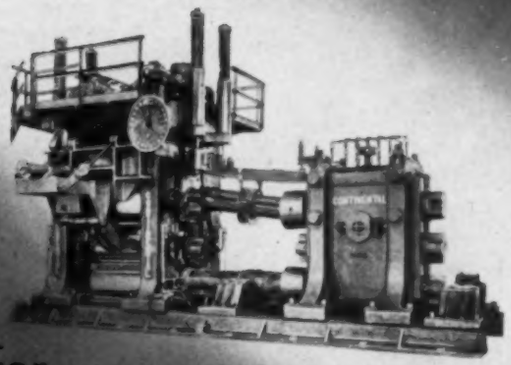
## J & L BLAST FURNACE SETS PRODUCTION RECORD

A new world's production record of 5,823,951 net tons of iron has been established on No. 3 blast furnace at the Aliquippa works of Jones and Laughlin Steel Corporation. This furnace, before shutting down for a complete relining, produced over two mil-









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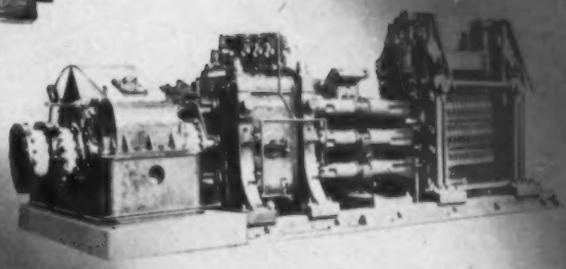
ROLLING MILLS AND EQUIPMENT



Continental

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Industry's Headquarters for Rolling Mills and Equipment Iron and Steel Rolls, Carbon and Alloy Steel Castings

lion tons more iron than has been produced on any other blast furnace. No. 3 furnace was blown-out on May 15, 1948, after operating almost continuously for fourteen years, eleven months and two days. During the entire "campaign" the furnace has had no repairs other than a relining from the mantle to the top of the furnace in 1942. The furnace hearth, and the water-cooled lower section of the furnace from the hearth up to the mantle which is known as the "bosh," have been in service since June 13, 1933. This was the first hearth in the world to have a diameter as large as 28 ft 6 in. The diameter was increased from 18 ft 8 in. in 1930. Due to business conditions, however, the enlarged furnace was not put in operation until 1933.

When the furnace was blown-out in February, 1942, for 21 days to be relined from the mantle to the top, it had produced 3,205,916 net tons of iron. This is almost equal to the maximum production of any blast furnace lining in the world. After the furnace was blown-in, it produced on the new lining above the mantle, 2,618,035 net tons. This gives a total of 5,823,911 net tons of iron produced for the entire "campaign" on this hearth and bosh.

**This J & L blast furnace produced over 2,000,000 tons more than any other blast furnace.**

In March, 1943, No. 3 furnace made a monthly world tonnage record. A total of 48,505 net tons of iron were tapped during the month. This is a daily average of 1,565 tons. During the last two weeks of March, 1943, the average production was 1,622 net tons per day and the furnace produced a record of 1,743 net tons on March 30, 1943.

J & L has been a pioneer in the construction of large blast furnaces. This work began in July, 1927, when the hearth of No. 5 blast furnace at Aliquippa was enlarged from 18 ft to 24 ft 6 in. This furnace became the first in the world to produce, in one year, an average of 1,130 net tons of iron per day. It was further enlarged to 26 ft 6 in. in November, 1943.

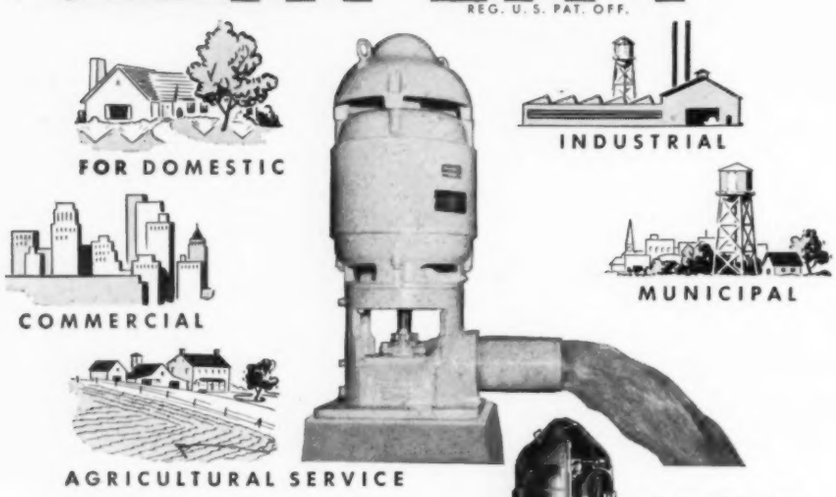
Harry Saxer, who was superintendent of the blast furnace department at Aliquippa at the time this furnace was enlarged, is credited with originating the enlargement program. Mr. Saxer later advanced to the position of general superintendent of the Aliquippa works. He retired on June 30, 1947, after serving in that post for more than 17 years.

After No. 5 furnace had proved its value, No. 4 furnace was enlarged from 18 ft to 27 ft in November, 1928.

No. 1 furnace, which is the same


PEERLESS HI-LIFT

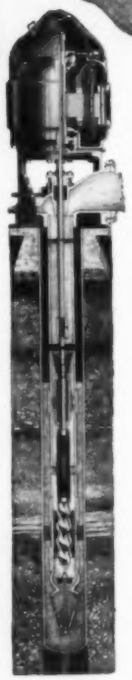
REG. U. S. PAT. OFF.




*The low cost pump for developing a maximum water supply from small diameter wells*

Here is one of the most simple and most positive of all deep well water pumping systems. The HiLlift pump has almost universal application because it's easy to understand, install and operate. In the Hi-Lift, Peerless utilizes an ingenious pumping element to literally squeeze water upward. Its pumping element consists simply of a hard chrome helically contoured rotor revolving in a similarly contoured rubber stator. That's all there is to this positive Peerless method of water lifting. It's the most forward step in pumping developed in the last 10 years, proved by thousands of successful installations in all kinds of service.

*Peerless Bulletin B-142 fully describes and illustrates the many advantages of the Hi-Lift Pump. Write for your copy today!*



CAPACITIES: 600 to 3300 Gallons per Hour from well depths to 600 feet.

Hi-Lift's pumping element is water lubricated, operates at half the usual pump speed; resists sand cutting abrasion and corrosion. When used with pressure tank, extremely high pressure may be developed without change or adjustment. These and many other Hi-Lift features are sure to make big savings in your water supply costs.

FULLY PATENTED BY R. MOINEAU & PEERLESS PATS.

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# HOW TO GET BETTER FORGINGS at Lower Cost

Assuming that the metallurgical and physical properties of the steel are correct for the service demanded of the forgings you make, getting better forgings at lower cost is largely a matter of modern equipment plus "know how".

The photograph shows a Brosius 6,000 lb. capacity Auto Floor Manipulator manufactured by Edgar E. Brosius Co., Sharpsburg, Pa., serving a 1,000 ton hydraulic forging press manufactured by The Hydraulic Press Manufacturing Co., Mt. Gilead, Ohio, both equipped with Timken tapered roller bearings to facilitate smooth, accurate, economical operation; reduce maintenance and lengthen equipment life.

Sixteen Timken bearings are used in the manipulator, including the wheels and drive mechanism as shown in the drawing. Timken bearings also are used in the hydraulic pump furnishing power to the press — a very exacting application, demanding extreme initial and lasting precision.

Specify Timken bearings for the equipment you buy; look for the trade-mark "TIMKEN" on the bearings that go in the equipment you make. The Timken Roller Bearing Company, Canton 6, Ohio. Cable address "TIMROSCO".

**TIMKEN**
TRADE-MARK REG. U. S. PAT. OFF.
*TAPERED ROLLER BEARINGS*

NOT JUST A BALL ○ NOT JUST A ROLLER ▭ THE TIMKEN TAPERED ROLLER ▭ BEARING TAKES RADIAL ⊖ AND THRUST →⊖← LOADS OR ANY COMBINATION ✳

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MEDART ROTARY STRAIGHTENERS
for round bar and tubular products
NO. 3 SIZE MEDART MULTICYCLE ROTARY STRAIGHTENING MACHINE
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NO. 3 SIZE MEDART TWO ROLL SINGLE MOTOR ROTARY STRAIGHTENING, SIZING AND POLISHING MACHINE
NO. 3 SIZE MEDART THREE ROLL ROTARY STRAIGHTENING MACHINE
MANUFACTURING ENGINEERS OF COMPLETE TRANSMISSION EQUIPMENT AND SPECIALIZED MACHINERY
MEDART
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size as No. 3 furnace (28 ft 6 in.), has been operating continuously since July, 1936, except for a thirty-day shutdown in 1944 for relining from the mantle to the top. This furnace has produced, up to May 31, 1948, a total of 4,870,493 net tons of iron on the same hearth and bosh. This tonnage is higher than from any other furnace in production today. No. 3 furnace which has just made the world's record and is being completely relined, is the only furnace with a greater tonnage record.

The five furnaces at Aliquippa are the largest unit of five blast furnaces in the world. The record production for the five furnaces was attained in March, 1944, when 172,989 net tons of iron were produced during the month.

## FONTANA MAY RECORDS REACH NEW HEIGHTS

All existing records in steel ingot production at the Fontana plant of Kaiser Company, Inc., were broken during the month of May.

Open hearth steel ingot in the amount of 80,103 net tons was produced as against the best previous month's tonnage, during or after the war, of 77,578 net tons.

Also ascending to new heights was the company's steadily increasing record of finished mill products, rolled and shipped to market; 61,184 net tons shipped in May was highest in Kaiser Steel's six-year production history, breaking a four-month old record of 53,519 net tons established in December of 1947.

## CONTINENTAL ENTERS POWER PLANT FIELD

Continental Foundry and Machine Company, operating plants in Chicago, Pittsburgh and Wheeling, scored the first entry of basic heavy industry into the power plant equipment field through the purchase of two established equipment producers. These are Vulcan Soot Blower Corporation, DuBois, Pennsylvania, and Northern Equipment Company, Erie, Pennsylvania.

The Vulcan Soot Blower Corporation, founded nearly fifty years ago, is one of the leading producers of mechanical equipment for cleaning high

*Here Today – Here Tomorrow*

# *Alliance* cranes stay on the job month after month - year after year

Steel plants have no 8-to-5 work day . . . no "time out" for lunch. Their production schedules must be maintained hour after hour—24 hours a day—week after week, month after month. That's why steel mills require rugged, dependable equipment—like the sturdy Alliance Open Hearth Charging Machine shown here. This specially-designed 75-ton Charging Machine loads the open hearth furnaces quickly and economically . . . then repeats this operation over and over again, throughout the three shifts of a 24-hour day.

Alliance cranes are built for long, rugged service, to help you maintain smooth-flowing production schedules at lower operating cost.

Alliance specialists have studied materials-handling problems for 50-odd years . . . have designed and developed thousands of cranes to handle all types of loads in many different industries. Let Alliance—World's Largest Builders of the World's Largest Cranes—develop the crane best suited to your plant methods and operations.

**LADLE CRANES • GANTRY CRANES • FORGING MANIPULATORS**
**SOAKING PIT CRANES • STRIPPER CRANES • SLAB AND BILLET**
**CHARGING MACHINES • OPEN HEARTH CHARGING MACHINES**
**SPECIAL MILL MACHINERY • STRUCTURAL FABRICATION**

**THE ALLIANCE MACHINE COMPANY**
*Main Office, Alliance, Ohio ★ Pittsburgh Office, 1622 Oliver Bldg.*

*Alliance*

pressure power and heating boilers.

Northern Equipment Company is the producer of Copes Boiler feed water regulators, Copes Reducing valves, Copes Desuper-heaters and related products, and enjoys an international reputation and market.

## NEW X-RAY ANALYZER HAS FIRST COMMERCIAL USE

A newly developed X-ray unit will receive its first commercial use at the Beaver Falls, Pennsylvania plant of Babcock and Wilcox Tube Company, officials of the company announced recently. The recently purchased fluorescence analysis unit, one of the first five such units constructed, makes possible non-destructive, rapid, quantitative analysis of the elemental constituents of metals, alloys, chemical mixtures and compounds, minerals and ores.

It is one of a unique set of three X-ray diffraction instruments acquired by Babcock and Wilcox Tube Company, which will broaden its facilities for industrial research in both the manufacture and application of tubing. The other two instruments, the Geiger counter spectrometer and X-ray diffraction unit, extend the scope of fine-structure analysis down to the ultimate architectural pattern of atoms in space, far beyond the ability of a microscope. The diffraction unit records its analysis on film, while the spectrometer speeds analysis by use of a Geiger counter and recording of the results on a chart.

The diffraction unit and Geiger counter spectrometer afford a new means of analysis of such industrial problems as determination of alloy phases and constituents control of heat treatment and recrystallization of cold-worked metals, grain size, preferred orientation, internal strain, magnetic properties, and structure of welds.

The new equipment will be used for fundamental research as well as for investigating practical metallurgical problems.

**No other one instrument**

**PERFORMS ALL THESE FUNCTIONS**

INDICATE AIRFLOW

INDICATE FUEL FLOW

SHOW RATIO OF AIRFLOW and FUEL FLOW

The Hays Visio-Ratio Gage is unique among indicating instruments because it performs the functions of three indicators—air-flow, fuel-flow and ratio.

Illustrated is a Visio-Ratio Gage which measures the flow of gas to a gas fired industrial furnace and the flow of air used for the combustion of the gas. Both these scales are calibrated in rate of flow in 1000 cu. ft. per hour.

The center scale is calibrated to show the percentage of excess of deficiency of air used to burn the gas with a range of 30% deficiency to 50% excess.

The spot at which the pointers cross over the center scale indicates directly the percentage of excess of deficiency of air used for combustion, eliminating the mathematical calculations which otherwise would be required with each change in flow of gas or air. The ratio used depends on the type of flame desired—oxidizing or reducing.

The HAYS CORPORATION
SINCE 1901
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA U.S.A.


## REPLACE STEAM ENGINES WITH DIESELS AT TCI

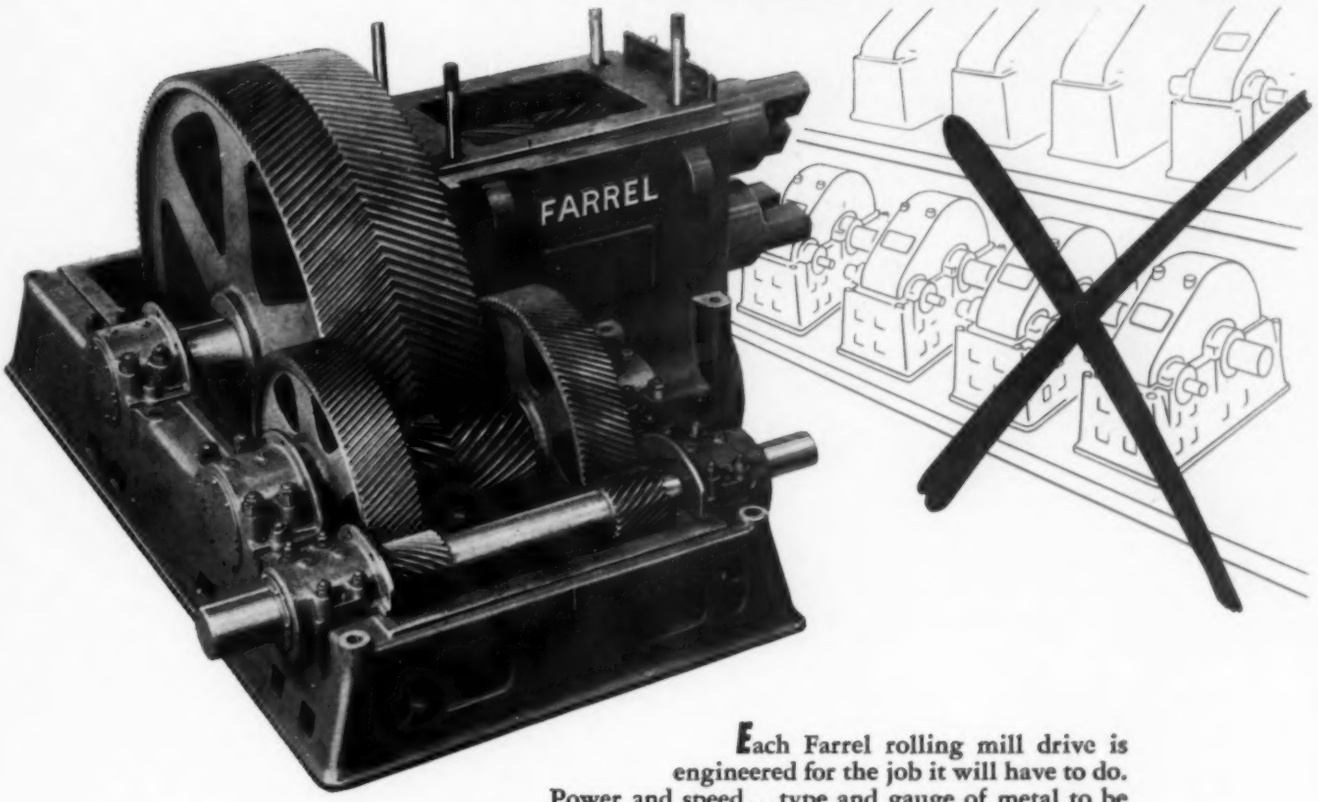
It was only natural that the steel industry should be one of the first affected by the advance of smokeless diesel locomotives in the railroad field.

Steel and the railroads grew up together in the United States. Every steel mill is serviced by many miles of internal track for moving in raw materials, shifting steel from one operation to another, and moving the finished product out to main lines where it may be dispatched on its way to consumers.

Replacement of steam with diesel locomotives in the yards of Tennessee Coal, Iron and Railroad Company, United States Steel's southern subsidiary, has made necessary the creation of a new method of emptying the big cast-steel pots used to haul liquid slag from blast furnaces to the slag pits.

Each mounted on a short underslung car frame between two four-wheeled trucks of standard railroad gage, these pots are dumped by the action of a piston, which tips the pot to pouring position. The piston has always been driven by steam, borrowed from the steam locomotive which pulls the train of pots. Since a diesel locomotive is actually propel-

# why *Farrel* rolling mill drives never come "off the shelf"




Each Farrel rolling mill drive is engineered for the job it will have to do. Power and speed... type and gauge of metal to be rolled... process (hot or cold)... nature of load (continuous or intermittent)... type of drive motor... all are taken into account before the size, material and type of construction are specified. Such *specialized* drives can't be production-line made and stocked for future sale.

Housings are of cast steel, Meehanite or welded steel construction, with either double-walled or single-walled deep base, depending on requirements.

Gears are continuous tooth herringbone, the famous Farrel-Sykes *Gear with a Backbone;* single helical; or a combination of single and double helical as used in the drive illustrated on this page.

Bearings may be either babbitt-lined steel cartridges or any approved make of anti-friction bearing.

Depending on conditions or requirements, lubrication may be by dip-and-splash system, by built-in pump driven by one of the shafts, or by separate lubrication system.

When you need a mill drive built to fit your specific requirements, call on Farrel. Our engineers will be glad to discuss gear drive problems with you at any time without obligation.

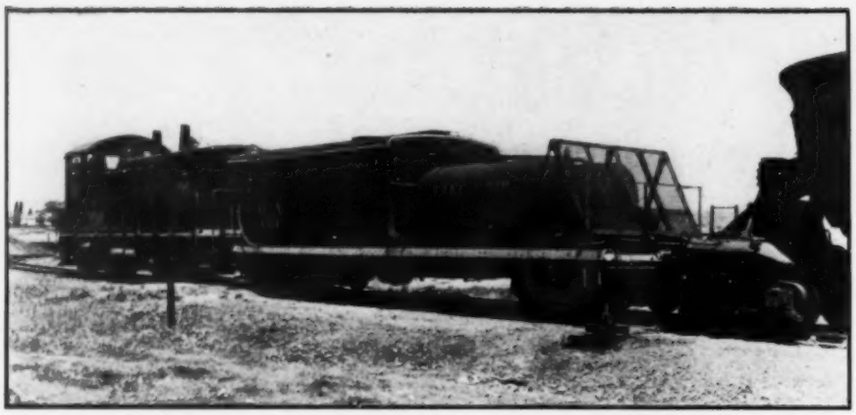
**FARREL-BIRMINGHAM COMPANY, INC.**
**ANSONIA, CONN.**

*Plants:* Ansonia and Derby, Conn.; Buffalo, N. Y.
*Sales Offices:* Ansonia, Buffalo, New York, Boston, Pittsburgh, Akron, Chicago, Los Angeles, Tulsa, Houston

FB-462

FARREL CENTENNIAL 1848 1948

*Farrel-Birmingham*



**Coupled between a diesel locomotive and a string of slag pots, this car, designed and built by technicians of the Tennessee Coal, Iron and Railroad Company provides the power to tilt the 15-ton containers of molten blast furnace slag, and to right them when they have been emptied. Compressors, which work when the locomotive is idling, maintain pressure in the two storage tanks which, transmitted to pistons attached to the pots, pushes them to their sides, spilling the slag.**

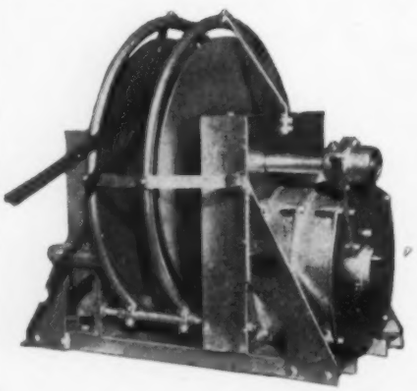
led by electric power derived from an oil-burning engine, no steam is provided for the tilting purpose. In this case the most logical successor to steam power was compressed air, since diesels themselves are equipped with air compressors to provide pressure for the brakes.

The slag pot-tipping task, however, requires much greater air power than provided by a normal diesel locomotive. The nature of blast furnace slag is such that merely tipping the pots is not enough. Slag quickly solidifies around the sides of the pot, forming what steelmakers call "skull" and a housewife might call a "crust." To jar this loose, it is necessary to tilt the pot with such force that its side strikes sharply against the frame of the car on which it is borne.

TCI technicians designed a special air-compressor car, which is coupled between the diesel locomotive and the first slag pot of the train. This car is divided into three sections. Two storage tanks with pipe connections to the pots are carried on a platform nearest the slag pots. Next, in a middle section, are the compressing machines, each driven by a 50 hp motor and maintaining 100 psi of air pressure in the tanks. At the end of the new car nearest to the locomotive is a closed compartment provided with seats for crewmen; this shelter represents a distinct improvement over the open tow cars on which the men formerly rode.

Whereas considerable work was involved in connecting steam fittings to the boilers of the old coal-burning locomotives, the new diesel system requires little more than a flick of the engineer's fingers. The air compressors are powered by the diesel's generators. A small lever transfers power from the wheels to the line which connects with the compressor motors, so that the pressure tanks can be filled while the locomotive is idling. A simple switch in the locomotive cab tips the slag pots and empties their burden in the slag pit.


A NEW LINE OF
EXTRA HEAVY DUTY
GLEASON CABLE REELS



SM SERIES

Spring Driven Geared Reel
For Electric Cables
125 Amps — 600 Volts
Continuous Contact
All Ball Bearings
Two-way Payout
Non-Revolving Springs
Fabricated Steel
Watertight
Replaceable Spring Motors
Adjustable Tension
8 Standard Sizes

These reels were developed to meet the unusually severe operating conditions found throughout the steel industry and are of exceedingly rugged construction.

The spring motors are interchangeable and removable so they may be replaced without handling loose springs. Replacement springs are supplied by the factory already installed in the housings and the replaced housings are returnable for credit.

The springs are wound on extra large hubs to minimize flexing at that point.

Adjustment of the spring torque is accomplished by means of a crank handle which is removable. A lock is provided to hold the drum in position during spring adjustment.

Improved current collector and brush rigging, with extra wide spacing, minimizes the possibility of electrical troubles.

J. L. GLEASON & CO., Inc., 209 Bent St., Cambridge, Mass.


## INCREASING PRODUCTION OF BRITISH STEEL


*By DAVID SACHS*

"INVESTORS CHRONICLE"

LONDON, ENGLAND

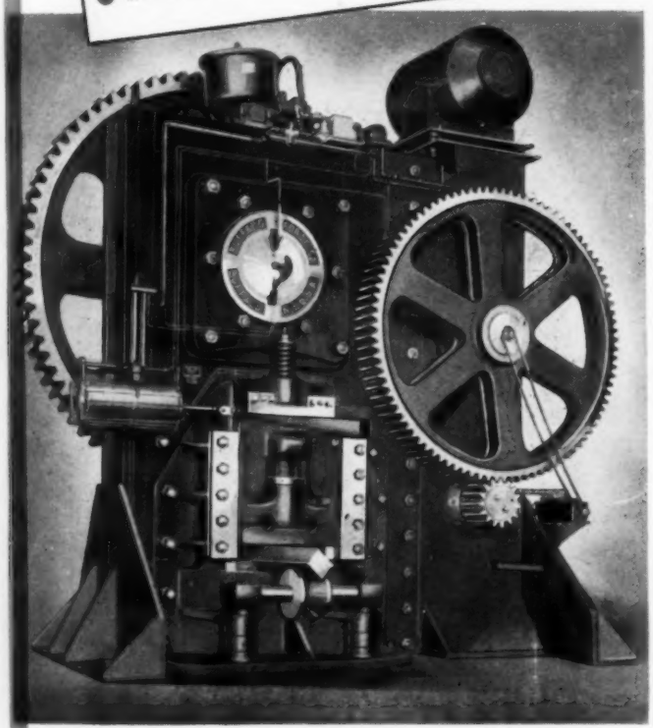

The steady and uninterrupted rise in steel production in recent months is one of the most satisfactory features of the economic scene in Britain. Steel, like coal, is the basis of industrial progress. Its supply in adequate quantities is, of course, indispensable for the restoration of Britain's productive power. But, in the short term, it is equally necessary for the fulfillment of the targets set for her dollar-saving industries, such as agricultural machinery to help her farmers, and for her export industries consuming steel such as vehicles of all kinds and innumerable engineering products.

Plans were laid some time ago for the expansion of Britain's steel producing capacity. As the official bulletin of the British Iron and Steel Federation pointed out in a recent num-

# Saving Money on these BILLET SHEARING JOBS!

- Shearing wrought-iron stay-bolt stock — High production — Clean square cut for full thread.
- In a seamless tube-mill — Square end cuts suitable for piercer requirements.
- In a steel mill — Cutting hot slabs leaving finishing roll — Continuous production.
- Automotive plants—Shearing high tensile valve stock at very high rate.
- Forge plant—Shearing square hard billets for crank and axle forgings
- In an arsenal — Shearing rifle barrel stock.
- In a Navy yard — Miscellaneous shearing.
- In a bar-mill — Shearing high tensile twisted bars.
- In a brass mill — Shearing rolled slabs and cast ingots.

. . . And many others!



This No. 17 Buffalo Billet Shear stands nineteen feet high and weighs 175,000 pounds.

## BUFFALO BILLET SHEARS

● Above are a few of the very successful applications of "Buffalo" Billet Shears in shops today, in many cases on punishing 24-hour shifts. The heavy all-around construction of "Buffalo" Billet Shears saves maintenance costs — and their speed on heavy stock means low turnout costs.

The "Buffalo" No. 17 Shears, at left, cut SIX 10″ round billets in a minute — SIX 9″ squares — SIX 28 x 4″ flats. Eleven standard sizes, to meet your need. Write for Bulletin No. 3295-A. See how you can cut more billets — cleaner and cheaper.

**BUFFALO FORGE COMPANY**

173 MORTIMER STREET BUFFALO 4, N. Y.

*Canadian Blower & Forge Co., Ltd., Kitchener, Ont.*

- BACK SPOT FACERS
- BAR CUTTERS
- BENDING ROLLS
- BILLET SHEARS
- DOUBLE END PUNCHES AND SHEARS
- LOCOMOTIVE SHEARS
- MILL TYPE SHEARS
- RAPID ACTING PUNCHES
- SINGLE END SHEARS
- SPRUE CUTTERS
- STRUCTURAL IRON WORKERS
- UNIVERSAL IRON WORKERS
- DRILLS FOR THE PRODUCTION LINE
- DRILLS FOR THE TOOL ROOM

ber, the fact that the development program got under way soon after the end of World War II is proving now of progressive benefit. The plans involved not only a vast modernization requiring the rebuilding and enlarging of furnaces but also the construction of major new steelworks of which the great plant now in course of erection in South Wales is the most striking example.

But apart from now beginning to enjoy the fruits of long-term planning, the industry has also benefited from its own measures of self-help, such as the decision to operate the steel furnaces on a seven-day week basis. It has been estimated that in this way an extra 750,000 tons of capacity might be secured, and already this continuous operation is reckoned to be contributing, along with the conversion of many open-hearth furnaces to oil-firing, approximately 600,000 tons annually to steel production. Clearly, as the new plants come into working, the benefits of continuous operation will be correspondingly greater.

Britain's Economic Survey for 1948 originally set a target for the industry of a production of steel ingots and castings amounting to 14,000,000 tons. Encouraged by the splendid performance of the industry in recent months, the Government has now raised this target to 14,500,000 tons. It is impressive to set down the actual production figures achieved. (It should be explained that monthly output is reported on the basis of an annual equivalent. This method may have some statistical disadvantages, but it does facilitate a comparison of the monthly results with the target for the year).

In 1938, Britain's production of steel ingots and castings was 10,397,900 tons. In 1947, production totaled 12,733,000 tons. The monthly production figures for 1948 (reported at their annual equivalent) are set out below:

| 1948 | Tons |
|---|---|
| January | 14,589,000 |
| February | 15,049,000 |
| March | 15,117,000 |
| April | 15,283,000 |

The April figures constitute a record in British steel production, but the performance of the industry in March was no less striking, since output inevitably suffered from the occurrence of the Easter holidays in that month.

In the light of this satisfactory trend of production, the new and higher target set for the industry may seem unduly modest. But such modesty has some justification. In the first place, monthly production at a rate superior to that of the target is necessary to offset lower production in those months when special adverse factors may be operating. Thus, all steelworkers are entitled to two weeks' annual vacation, and in the summer months output will inevitably show some decline on this account. Secondly, production can also suffer from the necessity of closing down plant for periodic overhauls.

But perhaps the most important reason why unbridled optimism regarding the future level of steel output would be out of place is the doubt about the provision of adequate supplies of the raw materials needed for steel making. This uncertainty may not, it is true, apply to the basis of

with the "SAFETY" BOX TYPE HOLDER

Mark ladle-test pieces with furnace number, year-code letter and heat numbers—in 50% less time with this type holder. Complete mark is made with one blow. Marks are in straight line, of even depth, easy to read—reduces errors in stamping and identifying tests. Eliminates danger of hitting fingers with hammer.

*Write for proposal on your needs.*

M.E. CUNNINGHAM CO.
SAFETY STEEL STAMPS

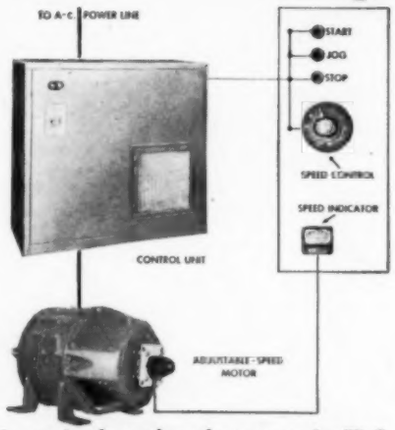
105 East Carson Street • Pittsburgh 19, Pa.

# Flexibility

## OF ADJUSTABLE SPEEDS FROM A-c. CIRCUITS

*Reliance V★S Drives built into this special machine automatically maintain any preset speed of spindle, rate of tool feed and depth of cut. Faster boring of casings and cylinders is the result.*

## Greater Output with Reliance V★S Drive




*Conveniently-packaged, space-saving V★S Drives are available from 1 to 200 hp. Two or more motors may be operated simultaneously from a single Control Unit.*

Whatever flexibility of operation is required to increase the output of a machine, Reliance V★S Drive can supply it—from A-c circuits. Quick, smooth starting and stopping and stepless speed changing—the basic V★S functions—may be supplemented by inching or threading, by reversing, maintenance of proper tension and a choice of many others to expedite any process. Simple, safe control with this *All-electric, Adjustable-speed Drive operating from A-c. Circuits* may be automatic or manual—at the machine or from any remote station. Let us send you *new* Bulletin 311.

**RELIANCE ELECTRIC & ENGINEERING CO.**

**1084 Ivanhoe Road • Cleveland 10, Ohio**

Appleton, Wis. • Birmingham • Boston • Buffalo • Chicago • Cincinnati • Dallas • Denver • Detroit • Gary Grand Rapids • Greenville, S. C. • Houston • Kansas City • Knoxville • Little Rock • Los Angeles • Milwaukee Minneapolis • New Orleans • New York • Omaha • Philadelphia • Pittsburgh • Portland, Ore. • Roanoke, Va. Rockford • St. Louis • San Francisco • Seattle • Syracuse • Tampa • Tulsa • Washington, D. C. Mexico City, Mexico • Montreal, Canada • Sao Paulo, Brazil

**RELIANCE A-C D-C MOTORS**

*"Motor-Drive is More Than Power"*

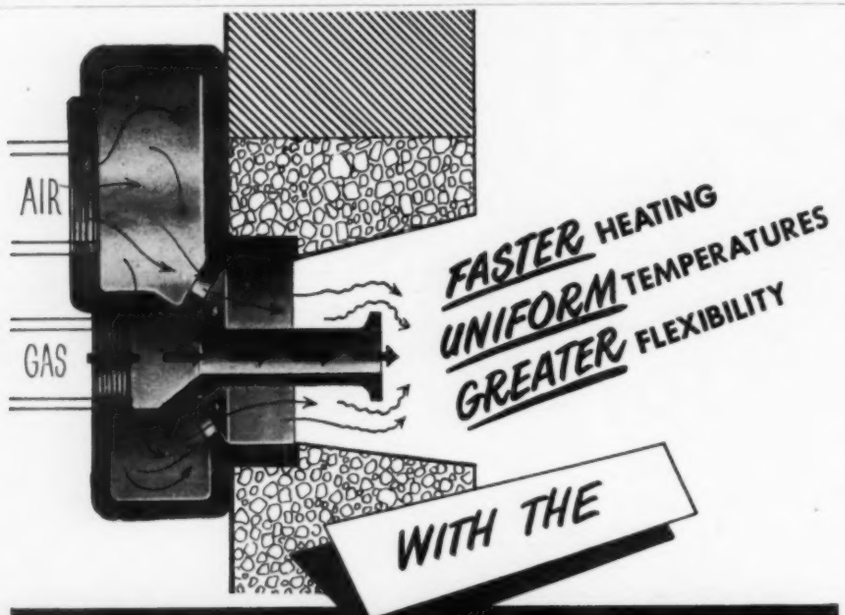
steel production, namely, pig-iron output, where the performance, as shown by the following table, compares favorably with the target figure of 9,200,000 tons.

PIG IRON PRODUCTION
(annual rate)

| 1948 | Tons |
|---|---|
| January | 8,726,000 |
| February | 9,169,000 |
| March | 9,303,000 |
| April | 9,433,000 |

Misgiving is greatest concerning the supply of scrap, and perhaps to a lesser extent the availability of rich iron ore from foreign sources. The largest source of scrap in Europe is, of course, Germany, where it has been estimated 10,000,000 tons are available. So far, for a variety of reasons, it has not been possible to import German scrap on anything like an adequate scale, but the introduction of currency reform in that country is likely to do a good deal in rendering Germans more anxious and efficient in making the necessary supplies of scrap available. Meanwhile, the British industry has been bending its efforts towards improving its own methods of scrap collection at home, and this has enabled it not only to insure a proper supply to the mills but also in recent months to arrest the disturbing drop in stocks which mounting production at home had in the circumstances inevitably involved.

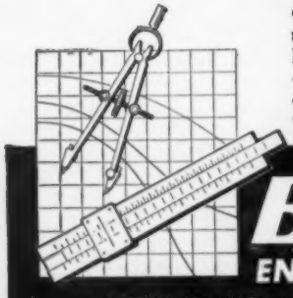
The importance of Britain achieving, and if possible surpassing, her 1948 program of steel production cannot be exaggerated. The Economic Survey spoke of steel as the worst bottleneck. The more successful the steel industry is the greater will its contribution be, not only towards hastening the completion of its own plans for greater productive capacity but also towards facilitating the tasks set for Britain's other capital and consumption goods industries. The House of Commons recently debated the question of more oil supplies, and the Government was pressed to give greater priority to the construction of oil refineries in Britain in the allocation of steel. If the improvement in steel production should make it possible to increase the allocation of steel to the plans already initiated for adding substantially to Britain's oil refining capacity, the benefit would be felt not only at home but in every country threatened with a shortage of petroleum products.


The unique patented design of this gas burner produces a flame which is very stable. The stability of the flame is not affected by extreme ranges of reducing or oxidizing air adjustments.

Outstanding results have been produced by the use of this burner on Car type Annealing Furnaces. Furnace temperatures as low as 400° F. and as high as 2450° F. can be produced without difficulty.

Write for bulletin.



BLOOM ENGINEERING CO., INC.
857 W. North Avenue Pittsburgh 12, Pa.


## NEW CARBURIZING SALT REMOVED BY IMMERSION

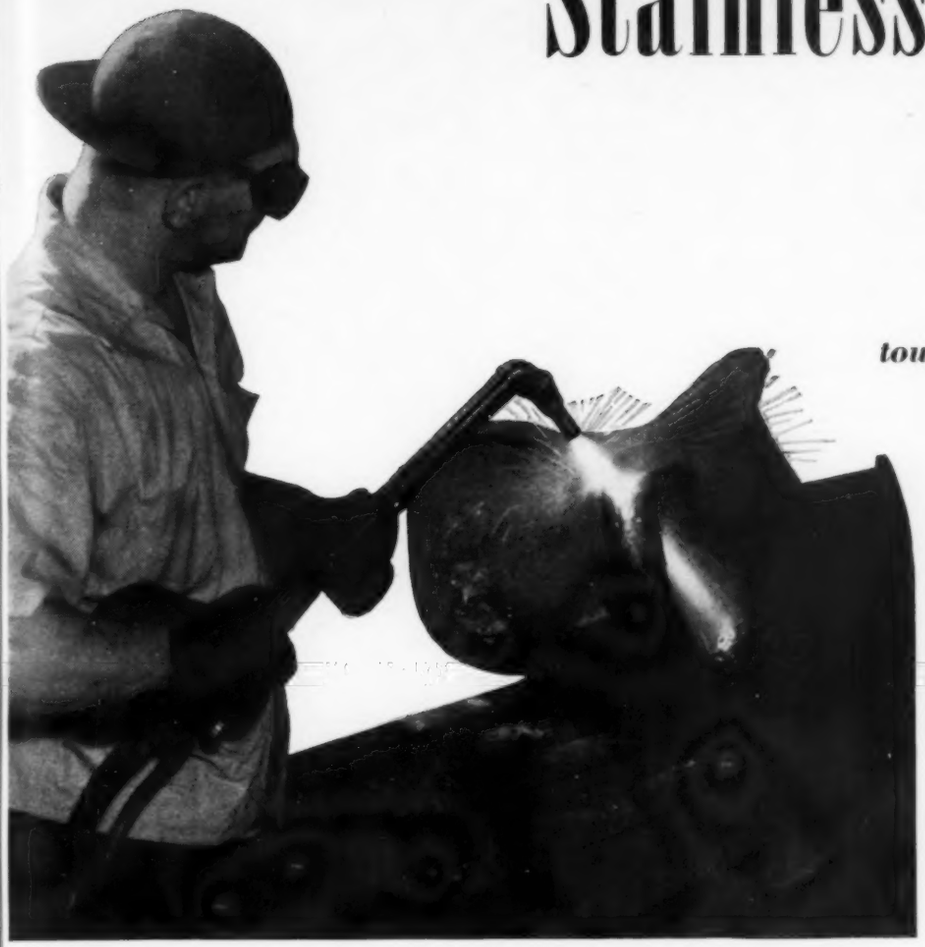
E. F. Houghton and Company recently announced a new carburizing salt which is readily removed from oil quenched parts by immersion in hot water. The new product is recommended highly for case hardening of hard-to-clean parts, at temperatures up to 1575 F.

This water soluble salt, known as "Perilton 'W'," is also used as a replacement for straight cyanide. Its many advantages over cyanide include: Time cycles cut in half; increased production; harder surface; easier to clean and leaving a cleaner surface; less cyanide breakdown; less fuming; and more pleasant for operators.

The recommended procedure in using this new product consists of a starting salt known as "Perliton 323" used for melting down of the bath. After the bath is broken in and ready for work "Perliton 'W'" is used for replenishments to compensate for drag-out losses.

Among the many advantages of the new salt are the production of a true carbon case; maintaining carburizing value when drag-out is normal, permitting replenishment with fresh salt; retarding grain growth be-

# Stainless Steel is TOUGH



***tough to cut, too—but LINDE makes the job easier . . . just as easy as cutting carbon steel***

LINDE's powder-cutting process overcomes the barrier to fast and economical cutting of stainless or chromium steels.

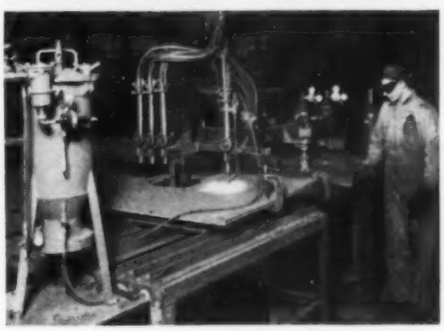
By means of easily installed attachments for standard oxy-acetylene equipment, powder-cutting can be done without substantial change from carbon steel cutting techniques.

***IN FOUNDRIES—***

by powder-cutting, risers are removed 20 times faster than by older methods. Removal of riser pads and gouging out defects can be done at considerable savings in cost.

***IN STEEL MILLS—***

a 12,000-lb. ingot can be powder-scarfed in 4 to 6 hours—about 1/10 the time required for grinding. Sizing of ingots, billets, and slabs, removal of hot tops, scrapping operations, and many other cutting jobs can be done in a fraction of the time previously required.



***IN FABRICATING PLANTS—***

a stack of twelve 10-ga., type-304 stainless sheets were powder-cut at 8 in. per min. . . . 4-in. I.D. by 8-in. O.D. flanges on ½ in., type 316 plates were made in 2 minutes of cutting time apiece.

If you work with stainless steel you will want to know more about this LINDE process. LINDE can supply the equipment you need, help you to set up, and supply the training help you need.

*Linde*

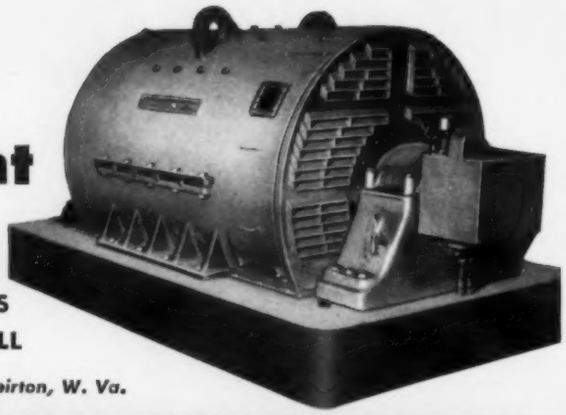
The word "Linde" is a registered trade-mark of The Linde Air Products Company.

**THE LINDE AIR PRODUCTS COMPANY**

*Unit of Union Carbide and Carbon Corporation*

30 East 42nd St., New York 17, N.Y. UCC Offices in Other Principal Cities

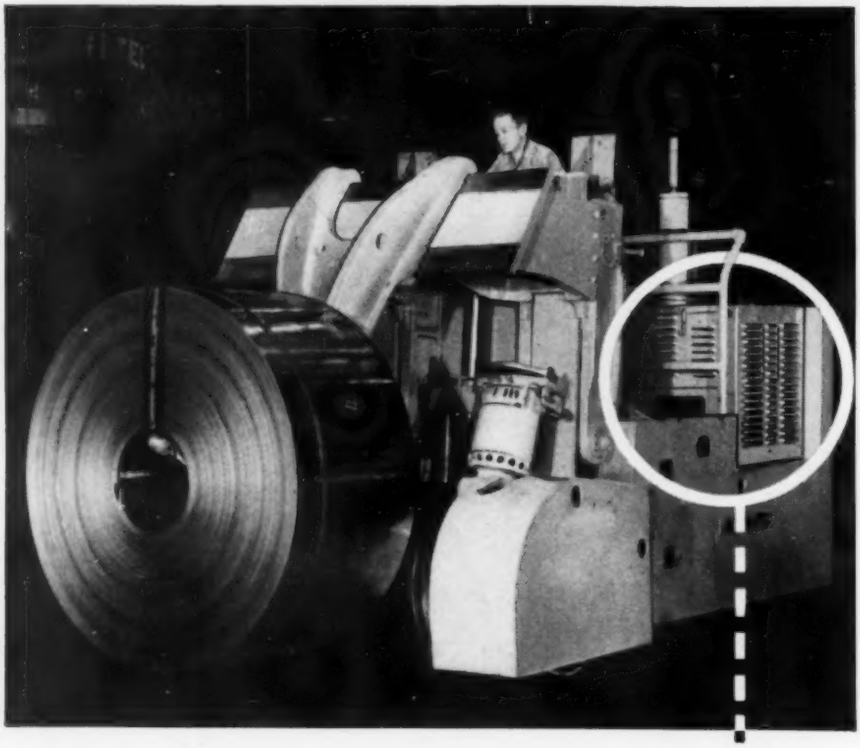
In Canada: DOMINION OXYGEN COMPANY, LIMITED, Toronto



**constant power**

**FOR THE WORLD'S FASTEST STRIP MILL**

*Weirton Steel Works, Weirton, W. Va.*

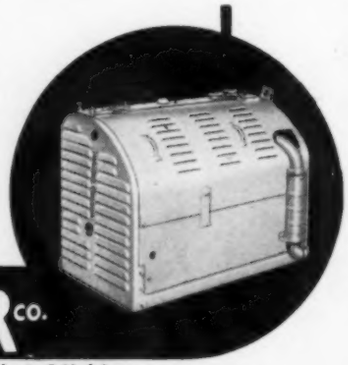


**constant power**

**WITH READY-POWER-EQUIPPED ELECTRIC TRUCKS**

Illustrated at top is one of two 2250 HP Motors at the Weirton Steel Works, Weirton, W.Va. furnishing *constant power* to drive the finishing rolls of the world's fastest cold-reduction strip mill capable of mile-a-minute production.

Equally constant and dependable is the power provided by the Ready-Power gas-electric unit on the "Automatic Skylift Giant" electric truck shown carrying one of the mill's 30,000 lb. rolls of finished strip. For electric trucks of any make or type, new or old, where constant power for hour-after-hour operation is needed—specify Ready-Power.



THE READY-POWER CO.

3836 Grand River Ave., Detroit 8, Michigan


## 1000 STAPLES A MINUTE!

**Alex Dunopewski empties tray of wire staples produced by one of seven modern, new staple machines installed at Joliet works of American Steel and Wire Company. The new machines, turning out 1000 staples a minute, are part of U. S. Steel's $800,000,000 development and improvement program. Each machine is capable of doubling production of old-type staple machines. They can produce any type staple up to 2 in. fence staples and as small as ¾ in.**

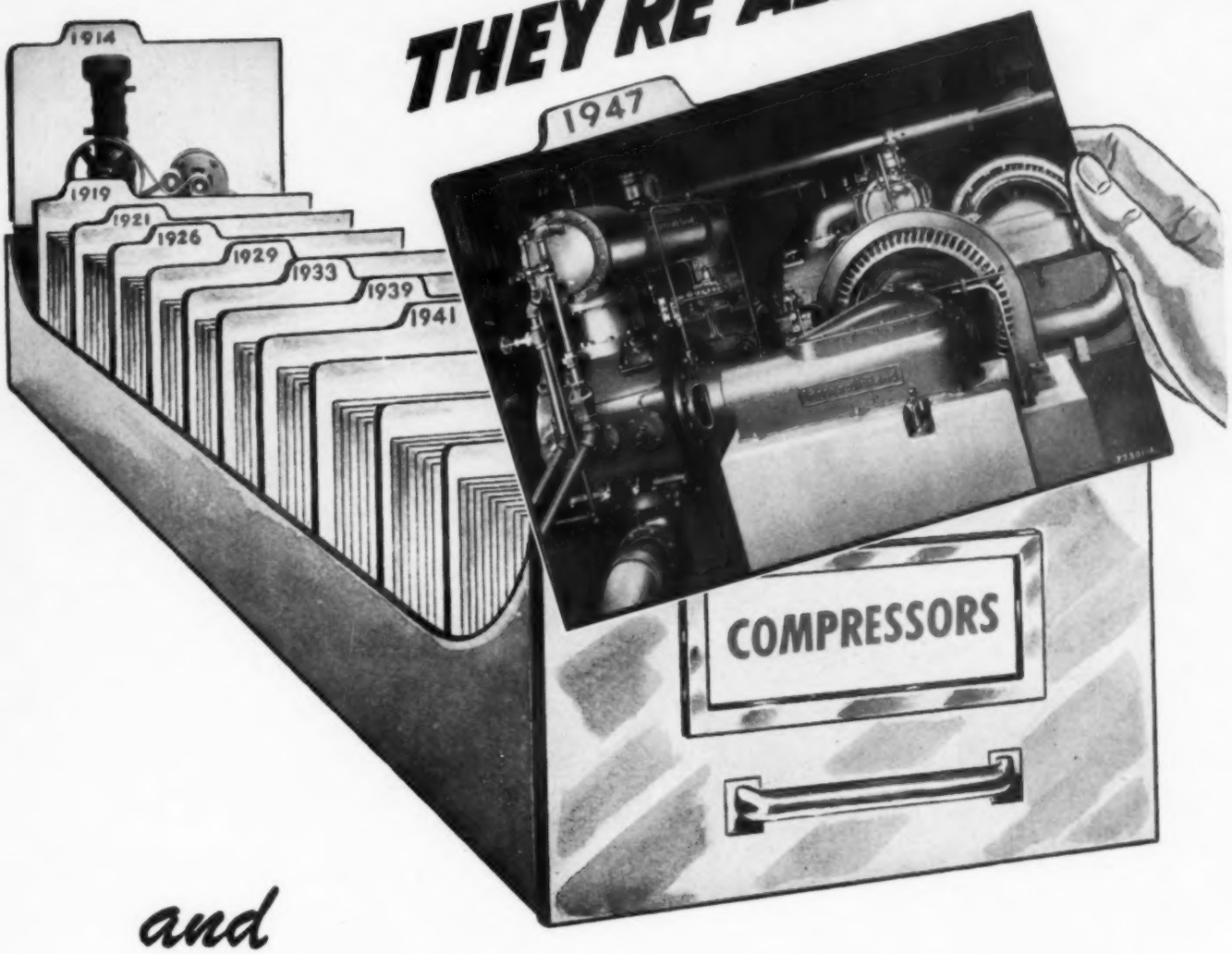
cause of lower temperature operation, which creates less thermal shock and less tendency to warp; salt washes off readily from threads or crevasses, so that no tumbling or sand blasting is necessary.

## MAGNET CONSTRUCTION REDUCES FAILURES

A design development of major importance to users of lifting magnets is announced by Cutler - Hammer, Inc. Statistics show that better than 60 per cent of magnet failures are due to moisture entering the coil. The new capsule-coil construction of the Cutler-Hammer lifting magnet incases the coil in an all metal, welded capsule from which all moisture is removed by a vacuum process prior to impregnating the coil with insulating compound under pressure. The coil winding is thus sealed completely against the entrance of moisture.

Another advantage of the capsule-coil construction is the ability to make "on the spot" repairs to the

# THEY'RE ALL I-R




*and*

# ALL OPERATING TODAY!

**34 YEARS** of trouble-free service...and still in daily use. That's the record of a Wisconsin manufacturer's first Ingersoll-Rand compressor, installed in 1914.

Many times since then more capacity was needed. Each time another compressor was installed it was an I-R. Today there are 12 of them, newest of which are three Type XRE, direct-connected, synchronous-motor-driven units. From experience, this manufacturer knows that Ingersoll-Rand compressors are economical, dependable, and long-lasting.

It is interesting to note that all these compressors were purchased through the same I-R Engineer. In each case his knowledge and experience played a major part in the selection of the proper machine for the job.

When you need Air-Power, let one of our trained engineers give you the same help with your problems.

COMPRESSORS • AIR TOOLS
ROCK DRILLS • TURBO BLOWERS
CONDENSERS • CENTRIFUGAL PUMPS
OIL AND GAS ENGINES

**Ingersoll-Rand**

11 Broadway, New York 4, N. Y.

184-1

**The new construction encases the coil in an all metal, welded capsule.**

magnet. Where formerly the complete magnet had to be returned to the factory for rewinding, the user can now quickly and easily remove the capsule coil, insert a spare replacement coil and restore the magnet to service immediately. The damaged coil which has been removed can then be sent to the factory for reinsulating. This feature is available in the 45 in., 55 in. and 65 in. magnet sizes.

When handling scrap pig iron and similar loose material the pole shoes of a magnet are subject to considerable wear. Removable pole shoes which can be removed after becoming worn and held in place by alloy bolts are a feature of this new construction.

## KLING ENGINEERING TO CONTROL ATWATER

With the recent death of K. W. Atwater, founder of the K. W. Atwater Engineering Inc., the company has passed into the hands of Kling Brothers Engineering Works of Chicago, manufacturers of metal working machinery and who also produce the "Lignalloy" bearings for the Atwater organization.

While Kling Brothers will continue to manufacture the "Lignalloy" bearings, the name K. W. Atwater Engineering Inc., and the Pittsburgh address in the Investment Building will remain unchanged.

Harry R. Gilchrist who was connected with Mr. Atwater for a number of years, has been placed in charge of the Pittsburgh office. Mr. Gilchrist, well known to the trade, will direct the sales of "Lignalloy" and service accounts for that area. Plans now in process include greater expansion and coverage in the near future.

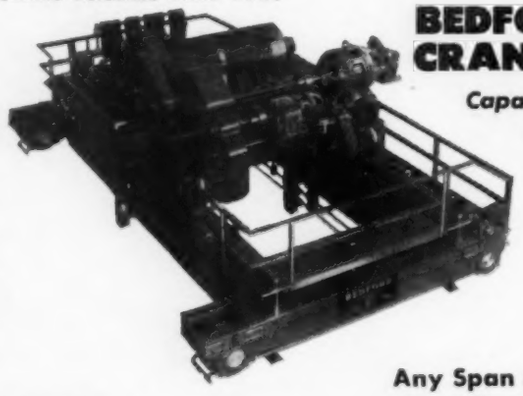
## DEVELOP CUT-OFF MACHINE FOR HIGH SPEED CUTTING

The Bridgeport Safety Emery Wheel Company, manufacturers of grinding machinery and abrasive wheels announces the development of a new, fully automatic abrasive cut-off machine designed for high speed cut-off of stock up to 2 in. square to lengths ranging from ¼ in. to 12 in. Steel, brass, plastics, porcelain—practically all materials used in industry are cut with speed and accuracy on the new Bridgeport Model 51.

The head assembly which consists of an 18 in. abrasive cut-off wheel driven through V-belts by a 10 hp motor is mounted on a rocker shaft running in Timken bearings and is

(*Please turn to page 121*)

CRANE BUILDERS Since 1903



**BEDFORD CRANES**

*Capacities 5 to 150 Tons*

Designed and Engineered to Meet Your Requirements

Any Span or Lift
Send For Your
Copy Of Catalog

ELECTRIC OVERHEAD TRAVELING CRANES
GANTRY CRANES • STEEL DERRICKS
BUILT TO YOUR SPECIFICATIONS
STRUCTURAL STEEL • STEEL BUILDINGS

**BEDFORD FOUNDRY & MACHINE CO.**

Engineers
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BEDFORD, INDIANA
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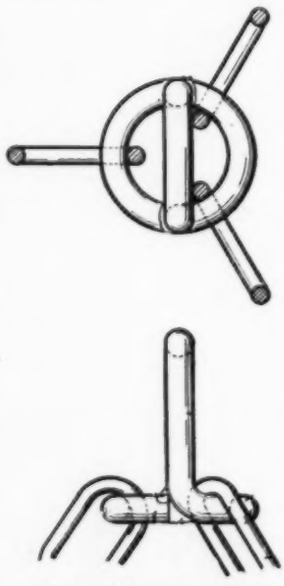
Gray Iron Castings

**LONG LIVED**
**Frictionless**
**Magnet Suspension Chains**



Suspension Chains for 55" and 65" Lifting Magnets that eliminate friction, so will last 4 times as long as old-fashioned Suspensions because:

1st: Each leg hangs free on ring and in magnet ears with no twisting or rubbing.

2nd: Suspension is made of high alloy steel — **heat-treated:** periodic annealing not necessary.

3rd: Each 55" Suspension is tested to 85,000 pounds; each 65" Suspension is tested to 115,000 pounds.

Prompt shipment from stock.

Patent Applied For

**DOWNTOWN COMPANY**
1836 Euclid Avenue CLEVELAND 15, OHIO

# the BILLETEER cuts conditioning costs 4 ways

### $ LOWER LABOR COSTS

One semi-skilled operator, using a Billeteer, can do the work of ten hand chippers —radically reducing labor cost and releasing man-power for less-killing, actually-productive work.

### $ SUSTAINED EFFICIENCY

Operation of the Billeteer imposes no strains on the worker. Quality and quantity of output never suffer from fatigue, grogginess, jitters, illness or "off" days.

### $ VALUABLE SCRAP RECOVERY

The Billeteer does not "burn up" hard-to-get scrap. Every chip can be saved . . . clean . . . classified according to analysis . . . ready for the charging box. In some mills, each Billeteer saves as much as 1½ tons of scrap a day.

### $ BILLET SALVAGE

Because of the low operating cost, the Billeteer can be used to salvage billets so badly seamed that it would be impractical to attempt to save them without the Billeteer.

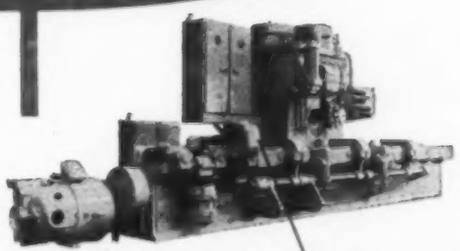
**LET US SHOW YOU** how much the Billeteer can save in your Billetshed operations.

*Engineered*

**FOR LOWER OPERATING COSTS**

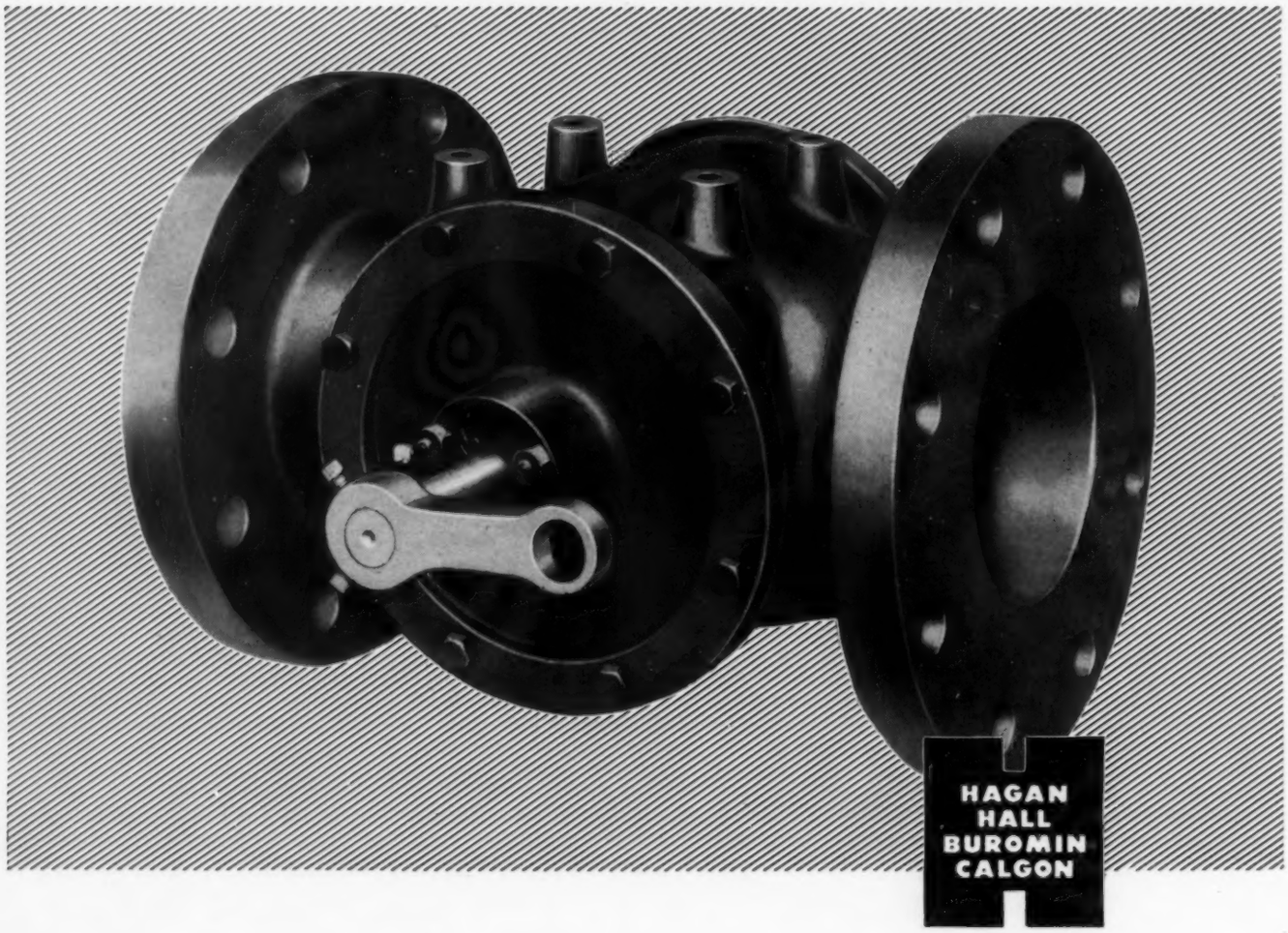
# BONNOT

**THE BONNOT COMPANY • builders of the BILLETEER • CANTON 2, OHIO**



• Bonnot Billet Inspection Tables • Charging Tables • Cold Saws Grinding Pans • Clay Mixers • Clay Feeders, Etc. •

# The Hagan V-Port Butterfly Valve




## gives smooth, accurate regulation over the entire range of operation

Accurate proportioning of fuel and air is essential in the modern furnace, where heat input may vary over a turn-down range of 10 to 1. The need is particularly great at the low rates because at this time steel is up to temperature and most sensitive to furnace atmosphere.

At a minimum flow, the differential across regulating valves is usually the greatest. Losses across the measuring orifice, duct work and burner decrease, so that loss across the regulating butterfly must increase by a corresponding amount.

In the Hagan V-Port Butterfly Valve all of these factors are taken into account in port design, and smooth, accurate regulation is secured over the entire range of operation.

The shape of the ports in this valve is such that full advantage is taken of the inherent sensitivity and accuracy of regulating equipment.

Hagan V-Port Butterfly Valves are made in standard pipe sizes. They are ruggedly built and accurately machined. Our engineers will be glad to give you full information.

Hagan Corporation, Hagan Building, Pittsburgh 30, Pa.

**HAGAN CORPORATION**

BOILER COMBUSTION CONTROL SYSTEMS
RING BALANCE FLOW AND PRESSURE INSTRUMENTS
METALLURGICAL FURNACE CONTROL SYSTEMS
THRUSTORQ FORCE MEASURING DEVICES

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- For securing any publication listed in permanent file just jot down numbers in space provided on mailing card.
- Be sure to include your name, address, title, etc., to insure speedy return.

JULY, 1948

## (1) Gear Motor

A bulletin is announced on a gear motor with advanced design for superior performance. In this new motor, all design considerations were worked from the drive point at output shaft back through to the motor, instead of the conventional approach. These motors are available in single, double and triple reductions providing a wide range of speeds with motor rates from one to sixty horsepower. It can be used with any type enclosure of a-c or d-c motor. (C404). Reliance Electric and Engineering Company.

## (2) Steel Mill Diesel Locomotives

Literature is available to you with complete details regarding the newest thing on wheels for steel mill operations. This is a 50-ton diesel electric locomotive designed especially for application in and around steel mills. If you are looking for information on diesel electric locomotives, we suggest that you circle number 2 below. Whitcomb Locomotive Company.

## (3) Asbestos Gaskets

Catalogs are available to you describing asbestos sheets and gaskets. This new material is homogenous in construction and dependable wherever a gasket is required. Every square inch of sheet has a uniform density, thickness and asbestos distribution. Exhaustive tests have shown that this gasket material is suitable for all the temperature-pressure combinations developed in connection with oil and all refrigerants, as well as steam, water, gasoline, ammonia, acids, alkalies and volatile vapors. (115B). Durabla Manufacturing Company.

## (4) Pickling Time Saver

A catalog on "Weldco" mechanical picklers is available. If you are pickling round, hexagon or square bars, coils, flats, tubing or sheets, this mechanical pickler is your best bet to increase tonnage at reduced cost. Easy to operate and control, the picklers save 40 to 60 per cent pickling time by combined mechanical agitation and chemical action, and eliminate the use of an overhead crane and operator. Youngstown Welding and Engineering Company.

## (5) Roll Forming Machinery

If you are interested in roll forming machinery, there is available to you a complete and concise booklet of cut-off machines, slitting machines, edge conditioning and straightening machines, stock holders, bulldozers and bending machines. The booklet is reprinted with photographs of applications and tabular information giving many details in which you will be interested. Tishken Products Company.

## (6) Jet Pipe Control

A new control principle is described in a catalog which is available to you. This new jet pipe principle converts the most delicate pressures or signals into rate of movement of a hydraulic cylinder. It consists of the jet pipe swinging freely on a hollow vertical pivot into which oil is pumped at high pressure. As the oil stream leaves the nozzle of the jet pipe it strikes at two closely adjacent distributor openings. The openings are piped to both ends of the cylinder which is connected to valve, damper or other type control. The slightest change in the signal moves the jet pipe, causing more or less oil to enter the right or left opening. This causes the cylinder to move either to the right or left to correct the signal variation. As soon as equilibrium is established, the jet pipe returns to its median position. For the tough control job where accuracy is a necessity and where valves, dampers, or other mechanisms must be moved, this new jet pipe control is the solution. (139). Askania Regulator Company.

## (7) Flexible Couplings

Flexible couplings are the subject of a 20-page catalog now being distributed. The catalog contains illustrated and descriptive information concerning the various types in which this coupling is offered, as well as a complete table on gear coupling ratings. Illustrations are included depicting typical coupling installations. (57). John Waldron Corporation.

## (8) Production Marker

A bulletin describing production line marking of seamless or light-wall tubing is available. It will mark round, square, hexagon and other shapes in sizes from 3/8 to 2-in. diameter. It stamps 1, 2, 3 or 4 sides on the same run at the rate of 300 fpm. It is available for production or job work. (LTM-1). Pannier Corporation.

## (9) Sodium Silicate Cement

A bulletin is available describing "Penchlor" acid-proof cement. This cement is a definite and superior sodium silicate cement because it is quick setting and self-hardening, due to the chemical reaction of the ingredients in the mortar. The cement powder is mixed with a sodium silicate solution of definite analysis. Initial set takes place in from twenty to twenty-five minutes after mixing. This cement has a proven record under a variety of acid conditions in steel mills. (6). Pennsylvania Salt Manufacturing Company.

## (10) Butterfly Valves

Including more than 70 specially made half-tone photographs, and tables keyed to drawings showing dimensions of valves, a new catalog on the butterfly or disc type valves they produce has just been issued.

The volume contains 52 pages and has a particularly easy-to-use index. It shows 11 basic types of R-S butterfly valves, including detailed elevations which reveal manual controls, extended shafts for automatic controls and finned boxes for high temperature service. The tables are keyed to the valve drawings to show dimensions in all sizes from 2 to 48 in. R-S Products Corporation.

## (11) Flexible Coupling Use

A new booklet entitled "Relief from Bearing Wear Grief" reveals a new answer to some old problems of power transmission loss and prematurely worn bearings. This booklet reveals how many plants are preventing the destructive waste of downtime caused by bearing failure, shaft failure and damaged equipment through the improper coupling of rotating shafts. This booklet describes the functions of flexible couplings. A thorough explanation and analysis is given to the principles by which couplings operate and their importance in relationship to the equipment it connects.

It presents practical helps to design engineers, plant engineers, master mechanics and maintenance men on how the use of proper flexible couplings prevents downtime caused by bearing failure, shaft failure and damaged equipment. American Flexible Coupling Company.

## (12) Materials Handling

A new comprehensive specification portfolio featuring illustrations, engineer's drawings, complete specifications and operating data on all models of Towmotor fork lift trucks and industrial tractors has just been published. The folder will prove of real value to anyone interested in the purchase of materials handling equipment, as it contains all necessary information in compact form for easy filing. The inside covers of the folder are used to illustrate a variety of interesting materials handling operations. A pocket on one side provides a neat file for a smaller, 4-page folder containing condensed specifications on the various Towmotor models in addition to individual specification sheets containing more detailed information on each model. Towmotor Corporation.

## (13) A-C Crane Control

A bulletin is available fully explaining a new principle of crane control that eliminates mechanical load brake. Called "Magnetorque," this new a-c crane control provides unusual hoisting smoothness and accuracy. It is a simple unit through which braking forces are exerted magnetically. The control governs the action of the hoist motor which is directly connected through the crane gear train to the hoist drum. The hoist motor drives the load both up and down but cannot be energized until the control unit has been excited. (C-39). Harnischfeger Corporation.

## (14) Strippable Coatings

Data and literature is available to you on a corrosion engineering service. This servcie can specify and assist in the application of the particular type of lining best suited to solve your problem. Recommendations are made solely with regard to the most efficient method of accomplishing the desired result. If you have a corrosion problem where lining would be a solution, it would pay you to investigate this service. Industrial Lining Engineers, Inc.

## (15) Steel Mill Valves

A 56-page catalog on Okadee valves is ready for you. These valves are suitable for a wide range of applications where low-pressure drop and positive shutoff are desirable features. The bulletin tells how these valves, in the interest of uniformity and standardization, have been made interchangeable. Illustrations show how the lever, rack and pinion and worm gear operated type of valves are made by utilizing one type of body. The book is complete with diagrams, dimensions, part numbers, curves and descriptive technical data. Included are installation photographs which show these valves in actual steel plant operation. (47-1). Okadee Company.

## (16) Backstop

A catalog is available describing a new backstop that provides a positive method for preventing reverse rotation on conveyor drives, elevator head shafts, windlasses, winches, and on all applications where reverse rotation should not occur. "Backrun" or reverse rotation, in some machinery operations, may cause serious damage to the machinery and the material being handled. In addition, expensive production delays may result. The gripping action of the new backstop takes place at the precise moment that forward rotation ceases. It reduces the possibility of shock or strain to a minimum. (10,080). Falk Corporation.

## (17) Power Brushes

A new brushing catalog, designed to simplify selection of the best brush for the individual job, has just been issued. The new 80-page catalog contains numerous illustrations of industrial brushing operations in addition to photographs and description of a complete line of power, paint, varnish and maintenance brushes. The informative new publication contains many innovations. Many of the photographs illustrate the various types of brushes in actual use. Osborn Manufacturing Company.

## (18) Silicone Products

A 30-page illustrated bulletin describing in detail G-E silicone products has been issued. The bulletin describes new silicone resins, oils, greases, water repellents, and rubber together with their many industrial uses. Charts and tables are included for handy reference. (CDR-57). General Electric Company, Chemical Department.

## (19) Dravo History

More than 50 years of activity in the field of power plant and pumping machinery installation for steel mills, public utilities, waterworks and industrial facilities are featured in a new booklet just published. The publication traces the history of Dravo Corporation back to 1891 when F. R. Dravo opened a sales agency in Pittsburgh for steam and power plant equipment. As the agency progressed, it undertook installation of the machinery and equipment, which ultimately led to formation of company divisions for the building of foundations, the production of sand and gravel and the manufacture of construction equipment. Activities in the power plant field also resulted in the development and manufacture by Dravo of space heating and air conditioning equipment. (902-A). Dravo Corporation.

## (20) Electric Motor Guide

Information on general purpose motors suitable for every industry is contained in a new "Handy Guide for Quick Selection of Electric Motors" just released. The new 12-page bulletin provides detailed specifications covering squirrel-cage induction motors and application data, range of sizes and speed torque curves on synchronous, wound rotor and direct current motors. It covers applications and features of gear-motors and multi-speed induction motors and carries an induction motor selection chart for units from one to 200 hp.

Attention is also called to a complete line of motor controls for every requirement of motor operation. Charts list the range of each type of control in voltage and horsepower. (51B6052J). Allis-Chalmers Manufacturing Company.

## (21) Surface Cleaning

An easily-controlled prepaint procedure for cleaning and surface treatment of ferrous metals to provide improved paint adhesion, is fully described in a new service report just issued. Method discussed is the "CrysCoat Process," in which a specially-formulated acid cleaner is applied to metal surfaces as work is routed through a three or more stage pressure-spray washing machine. "CrysCoating," the report states, performs the following three operations at the same time: (1) removes light soils, grease, spinning compounds and shop dirt from work; (2) improves paint grippage by imparting on surfaces a thin, crystalline phosphate film that actually becomes part of the metal itself; and (3) retards rusting of metal surfaces between cleaning and painting operations, and localizes corrosion if painted finishes become scratched or marred during product use. New service report features an application check chart offering detailed data on "CrysCoating" procedures, including recommendations on specific solution concentrations, temperatures, time cycles, and pH range of solutions. Oakite Products, Inc.

## (22) Industrial Batteries

Plant managers, industrial engineers, foremen, service men, purchasing agents, and others whose problems embrace the purchase and maintenance of materials handling systems, will want to obtain two new six-page, two-color, technical brochures on industrial truck batteries, recently announced. The new literature includes illustrations, descriptions, and full technical data on the Gould "Thirty" and the Gould "Kathanode" batteries. An unusually helpful element in the Gould "Thirty" brochure is a giant exploded-view showing every construction feature of this battery and emphasizing the exclusive glass tape feature used in insulating the positive plate. Text explains how the battery has been specially designed for use in industrial trucks and explains the features which enable the battery to

deliver approximately 30 per cent greater ton-mileage during the life of the battery than conventional batteries. Engineering specifications include: (1) ampere hour capacity and kilowatt hour capacity for 6 and 8 hour periods of use, (2) ampere discharge rates for 6 hour periods of use, (3) both tray and electrolyte weights, and (4) cell dimensions. These specifications are given for the standard height (XVL-P), high type (XL-P), and extra-high type (AMH-P) batteries. In conclusion, information on the new Gould laboratory; two-plant delivery facilities; and field service, is given.

The material contained in the "Kath anode" brochure is similar to that contained in the "Thirty" brochure. It illustrates and describes the features which make this older member of the Gould line desirable where uniform heavy truck duty is encountered. Engineering specifications are given for (1) standard height, (2) standard height extra capacity, (3) intermediate height, (4) high type, and (5) extra high type batteries. (GB-573 and GB-574). Gould Storage Battery Corporation.

## (23) Centrifugal Pumps

For the first time, De Laval single stage pumps have been included in a single comprehensive catalog presenting outstanding features of design and construction, listing pump ratings and incorporating essential dimensions. With this catalog, engineers can select the required pump, estimate motor size and plan approximate installation dimensions. In replacing several separate leaflets for these pumps, the one catalog now contains information for all G, I, K, L, M and P single stage, single and double suction pumps. The catalog also gives brief descriptions of such optional features as mechanical shaft seals, self-priming systems and vertical mountings. (83-29). De Laval Steam Turbine Company.

## (24) Pallet Handling

A new two-colored 20-page bulletin on pallet-system applications, hand lift and worksaver pallet truck models, and recommended pallet design is announced. Six full pages are devoted to pictures illustrating uses of the pallet system. Typical uses include hauling goods from one process to another, hauling finished goods to the shipping room, storing goods both within the plant and in the plant yard, and performing general plant transportation jobs. Two pages are devoted to drawings and text on recommended pallet design. Double-face reversible pallets, double-face nonreversible pallets, four-way entry pallets, and single-face pallets are discussed. Four pages are devoted to cutaway illustrations of hand truck mechanisms and text on advantages of both mechanical and hydraulic lifting mechanisms. Charts recommend the correct trucks for use with double-face and single-face pallets and give capacities, lift frame specifications, ground clearance, and structural data for the various models. Five pages are devoted to the "Worksaver" hand truck. (P-673). Yale and Towne Manufacturing Company.

## (25) Grinding Wheels

Just published is a 28-page catalog and price list covering high-speed grinding wheels used by steel mills. The catalog gives detailed information on "Royalite" resin-bonded grinding wheels and its vulcanite and "Corvite" rubber-bonded wheels. (MG-27). U. S. Rubber Company.

## (26) Modern Handling Methods

Production and warehousing operations in a paint manufacturing plant normally involve an amazing number of handling operations. Add to this the handicap of operating in multi-storied buildings and handling becomes a truly complex problem. Such was the case at Glidden Company, Cleveland, Ohio, producers of paints and finishes, whose handling methods proved effective stumbling blocks to production and storage efficiency. A thorough analysis of the entire handling problem revealed that the same handling operations, converted to a modern mechanized system, could be transformed from a "handling headache" to a series of rare opportunities to increase productive output, lower production costs and gain full use of every inch of available storage area.

How Glidden Company put modern handling methods to work in its plants and warehouses, installing a complete new system built around a fleet of Towmotor Fork Lift Trucks and Tractors, is explained in a job study which is available. This latest in a series of authentic, factual studies of handling problems is illustrated and informative and contains data of value to everyone concerned with increasing materials handling efficiency. (JS75). Towmotor Corporation.

## (27) Fluid Meter Data

Just issued is a revised bulletin entitled: "Fluid Meters for Steam-Liquids-Gases." This 40-page booklet is divided into ten different sections discussing, among other things, flow mechanisms, primary elements, integrators, auxiliary recorders, accessories, and installation features. Each section is well illustrated by photographs and drawings of the equipment discussed as well as by diagrammatics which aid in understanding the operation. Also shown are representative chart records taken from actual fluid meter installations. These serve to illustrate meter operation. These fluid meters are supplied as indicators or recorders or both. They may also be equipped with a six-unit cyclometer type integrator which counts total fluid flow in gallons, pounds or cubic feet. They are easily adaptable to air-operated control. (301-D). Bailey Meter Company.

## (28) Improved Emulsion Cleaner

Complete data on an emulsion cleaner is now available in a product data sheet. This cleaner is considered a superior replacement for either straight petroleum solvents or non-flammable solvents used for industrial cleaning. It has proved to be equally efficient for cleaning ferrous or non-ferrous metals. It also forms a stable non-foaming emulsion with water, hot or cold. This product has many advantages over regular solvent cleaners. It possesses higher solvency properties than do straight solvents. It readily mixes with water, is attracted to water in the spray rinse, and hence is more thoroughly removed than is a straight solvent which resists water. "Houghto-clean 220" contains a powerful corrosion inhibitor. It is non-toxic, and does not present a fire hazard. E. F. Houghton and Company.

## (29) Condensed Truck Catalog

Featuring a tabulated summary of principal specifications of its fork-lift trucks, towing tractors and tructractor models, a new 4-page condensed catalog has been issued. Dimensions, weights, capacities, and turning radii are given for all models, both gas-powered and electric battery-powered. (TC-16). Clark Tructractor division, Clark Equipment Company.

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### (30) Perpetual Water Strainer

A recently published folder describes a new duplex strainer now being manufactured. This rugged, compact mechanism provides continuous clean water for industrial, processing and utility purposes. Its unique feature is the incorporation of two basket strainer units within the main casing, arranged so that either can be cleaned while the other is functioning. The switch from one strainer to the other is accomplished by a single handwheel which operates a positive-acting, non-fouling valve. Located in the outlet end, the internal mechanism of this continuous-seat valve is subject to virtually no wear from impingement and erosion. The booklet shows engineering drawings which indicate part dimensions for the six standard size strainers that range from 4 in. to 24 in. pipe-size service. Semi-log graphs show pressure loss and flow rates. (37). R-S Products Corporation.

### (31) High Alloy Stainless Steel

An 8-page bulletin has just been issued on a high alloy low carbon austenitic stainless steel known as "Durimet 20." Introduced just before the war, this alloy has proved to be markedly superior to standard 18-8 stainless steel analyses for certain severe corrosive services, especially in the handling of sulphuric acid. In the cast form it contains 29 per cent nickel, 20 per cent chromium, 1¾ per cent molybdenum, 3½ per cent copper, 1 per cent silicon and 0.07 per cent max carbon. In the wrought form the copper and silicon contents are modified slightly. "Durimet 20" is recommended for use with about 125 corrosive solutions. Particular attention is given to service where standard 18-8 stainless steel may be limited in resistance to attack. Its resistance to sulphuric acid and its own limitations for this corrosive are thoroughly charted. (112). Duriron Company.

### (32) Bushing Stock Guide

Just announced is a handy, double-purpose standard stock guide for the convenience of users of bushing bronze. The guide is printed attractively in two colors on cardboard stock. Open flat, it serves as a handy, easily read wall chart, already punched to facilitate hanging. However, the guide is standard file size, 8½ x 11 in., for those who choose to use it in this manner. The guide lists the complete range of standard diameters available for immediate delivery and also gives approximate weights of both centrifugally cast tubular bar stock and chill-cast solid round bars. Shenango-Penn Mold Company.

### (33) Wire and Cable Handbook

The new Rockbestos catalog and handbook is just off the press and ready for distribution. It is much bigger, better and more useful than the edition it supersedes—expanded 50 per cent to give a better cross-section of our complete line of more than 125 different heat and flame resistant wires, cables and cords of standard construction designed for severe operating conditions. The text is completely new and up-to-date, tabs separate sections for ready reference, it opens flat for convenience and contains many new features and additional technical data. (10F). Rockbestos Products Corporation.

### (34) Solvent Cleaner

How an emulsifiable solvent cleaner in conjunction with pressure-spray washing equipment removes grease, oil, chips, shop dirt, etc., from metal parts between production operations, is described in an interesting article appearing in a recent issue of Oakite News Service. Oakite Composition No. 97, the article reports, has a duplex action that: (1) quickly wets, penetrates and dissolves oil and grease; and (2) has the ability to lift off the thinned soils and particle dirt, buoying them to the tank surface so that they may be either skimmed or overflowed for disposal. Other particle dirt is so saturated that its attachment to the metal surface is broken and it can, therefore, be easily rinsed away, it is said. Because of the almost neutral pH of Oakite Composition No. 97, it may be used on all metals, including aluminum, without etching or pitting.

In extensive tests this material has demonstrated the ability to remove dirt and smut particles from metal surfaces where solvent vapor degreasing has failed, the manufacturers state. Other advantages reported are: (1) it eliminates fire and health hazards, because its emulsions are aqueous and non-toxic; (2) it may be used in an industrial washing machine and shows no tendency to foam excessively; and (3) it is admirably suited for removing oils, greases and shop dirt prior to inspection of work in process, or before spot welding, ammonia gas carburizing or electrocleaning before plating. Oakite Products, Inc.,

### (35) Magnet Sub-Assemblies

A concise four-page illustrated booklet devoted to a description of permanent magnet sub-assemblies, has been issued. The booklet describes how these magnetic sub-assemblies eliminate assembly line rejects, the high cost of test equipment, breaking and chipping losses, and the expense of shipping semi-finished magnets. Among the sub-assemblies illustrated are the magnetic focusing sub-assembly, the "Titan" valve sub-assembly, the magnetron sub-assembly, the cable clamp sub-assembly, a radar jammer tube, and a snap action switch. (CDM-16). Chemical Department, General Electric Company.

### (36) Inert Gas Production

An extremely informative booklet, which goes into the mechanics and economics of producing inert gases right at the industrial user's plant, has recently been published. Simplified diagrams of the various equipment units and their positions in a complete assembly, plus installation photographs, give visual ideas of plant layouts for these widely-used systems. In easily-understood language, the text treats of such matters as: How the generators work; cost of production; the chemistry of inert gases; desiccation, compression and nitrogen generation. For those manufacturers and processors who are users of inert gases now, or those who would like to investigate the possibilities of applying them to present or future work, this booklet offers a fund of instructive, practical answers to primary questions. Inert gases already have proved their reliability for many applications . . . purging of pipe lines and tanks; the blanketing of explosives and combustibles; flushing stills and reaction vessels; agitating batches during cooking; fighting fire; controlling chemical reactions; and a host of other essential uses. The full scope of their possibilities is yet to be explored, and this condensed treatise on their low-cost generation should inspire many new ideas. C. M. Kemp Manufacturing Company.

### (37) Fan Speed Control

A new 20 page booklet is available entitled: "Precision Speed Control for Boiler Draft Fans with the Regutron Controlled Magnetic Drive". The bulletin discusses principles of operation with graphs, diagrams and installation pictures, and describes how adjustable speed magnetic drive with "Regutron" control provides wide range, smooth, precise, rapid and dependable speed control. (4400-TEC-1078) Electric Machinery Manufacturing Company.

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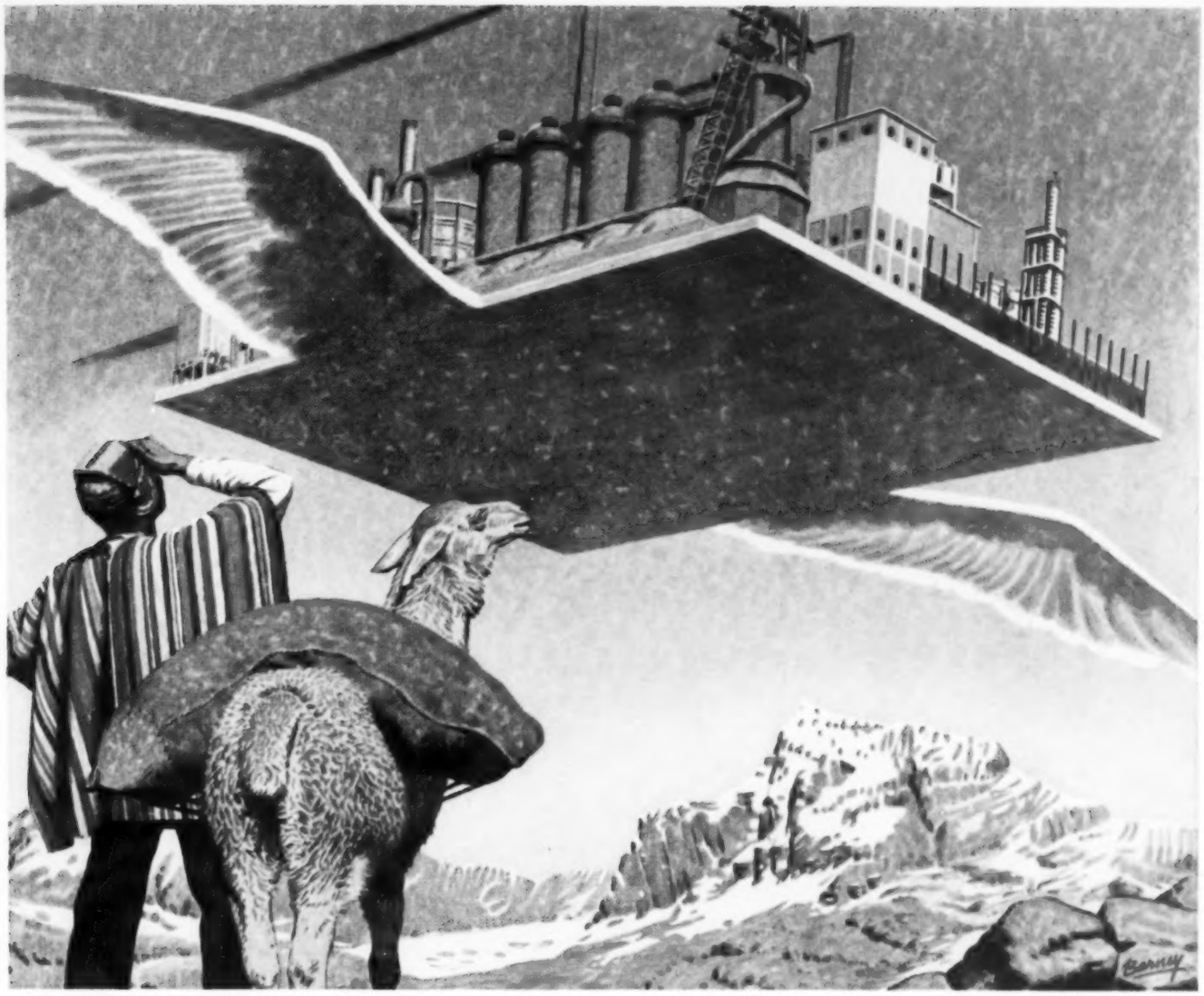

# The steel plant that flew to Chile

THE first integrated steel plant to be built in Chile may well become known as "the steel plant that flew there" . . . because so many of the men, plans, and materials involved in this huge project are traveling to the site by air from the United States.

Koppers Company will participate in management and supervision of the plant in all stages of its construction and subsequent operation.

The new plant will be located at Concepcion, Chile, on San Vicente Bay. It will cost in excess of fifty million dollars, and will produce 200,000 tons of finished steel a year.

Plans call for a blast furnace to make pig iron; coke ovens to make coke, with auxiliaries to handle tar and light oils; equipment to purify the coke oven gas, and a gas transmission line to serve industrial and domestic users; open hearth and electric furnaces; a Bessemer converter; and finishing mills to produce a wide variety of flat-rolled and merchant products.

Perhaps Koppers can help *you* perform some specialized engineering and construction job. We welcome your inquiries. Koppers Company, Inc., Engineering and Construction Division, Pittsburgh 19, Pa.

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**Designing and erecting coke plants,** by-product plants and other industrial structures is just one way in which Koppers serves industry and you. Koppers also produces chemicals from coal. It manufactures couplings, roofing, paving materials, propellers, piston rings. It is a leader in the wood-preserving industry. There are many Koppers products or services that will help *your* business.

# SHORT IN COST...
# L-O-N-G IN SERVICE...

## This MONEL Pickling Crate has been on the job for 13 years

THE Follansbee Steel Corporation of Follansbee, W. Va., wanted a pickling crate . . . one that would carry a two-ton load of high silicon electrical steel sheet . . . one that would last a long time with a minimum of upkeep expense.

They chose MONEL* as the fabricating material; chose it because of MONEL's exceptional resistance to hot acids and its steel-like strength. And a wise choice it was, for today *—13 years later*—the MONEL pickling crate is still in service!

During war years, when ever more production was needed, the MONEL pickling crate carried a double load of armor plate: 4 tons instead of 2. Yet, even with this increased burden, the crate more than lived up to expectations.

This is but one of thousands of instances where MONEL has shown its outstanding superiority under severely corrosive conditions.

In addition to high strength and corrosion-resistance, MONEL offers *workability*. MONEL can be fabricated by ordinary shop methods without special tools or equipment. MONEL can be welded. And what is extremely important—welded MONEL seams are corrosion-resistant.

Check your own plant installations today. You may find many places where the versatile INCO Nickel Alloys can save you money. For further information, contact your nearest INCO distributor. He will gladly help with your metal selection problems. *Reg. U. S. Pat. Off.

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**FOR MINIMUM MAINTENANCE**

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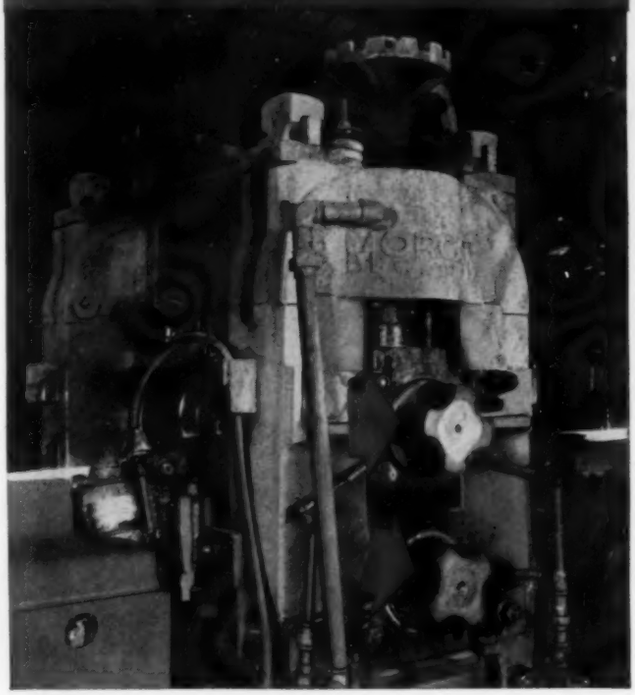
**THE INTERNATIONAL NICKEL COMPANY, INC.**
*67 Wall Street, New York 5, N. Y.*

## Savings here–



## Start here!

A-B-K roller neck bearing with separate collar.

# A-B-K Laminated Plastic Bearings Wear Longer–Cost Less to Maintain

Are excessive bearing maintenance and replacement costs eating into your profit-per-ton? Chances are it will pay you to check—and to replace conventional bearings with modern A-B-K Laminated Plastic Bearings.

In a wide range of mill applications, A-B-K bearings actually *outwear metal*. They are exceptionally slow-wearing and heat resistant . . . will not distort under shock. And because A-B-K material holds gauge longer, fewer oversizes and fewer adjustments are required . . . In addition, A-B-K Laminated Plastic Bearings are successfully lubricated with *water*. You *save* the cost of oil or grease. Power consumption is reduced, too, because of A-B-K's low co-efficient of friction.

Consider these advantages for specific applications in your mill. A letter, phone call or wire will bring an experienced A-B-K representative to your office. He will place our engineering and production facilities at your disposal.

A-B-K slipper bearing, with patented reinforced edge. (At Right: phantom view)

AMERICAN Brake Shoe COMPANY

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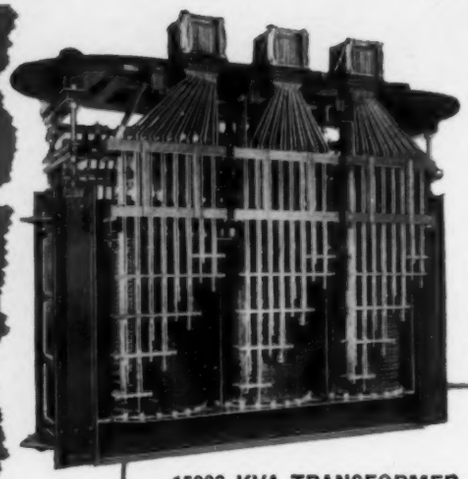
A·B·K
Laminated Plastic Bearings

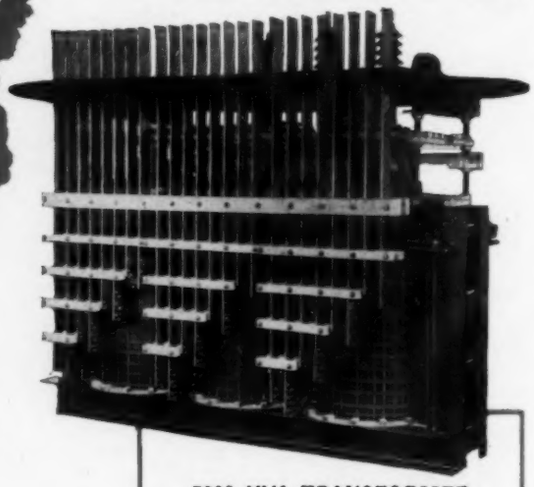
# Over 1 MILLION KVA of Pennsylvania Furnace Transformers

## Now in Service!

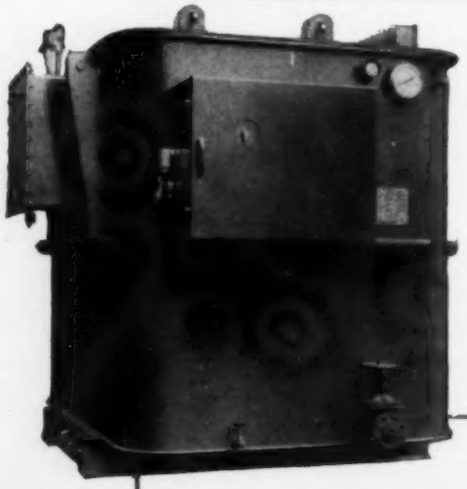
YES, Pennsylvania Furnace Transformers, totaling over 1 Million KVA, are supplying power to hundreds of electric furnaces. The successful operation of these transformers has given Pennsylvania Transformer Company a noted reputation in the Furnace Transformer field. For over 35 years, Pennsylvania Engineers have closely followed the development of Electric Furnaces. They fully understand the problems of Electric Furnaces and their relation to Furnace Transformers.



15000 KVA TRANSFORMER
for operating a 75-Ton Furnace

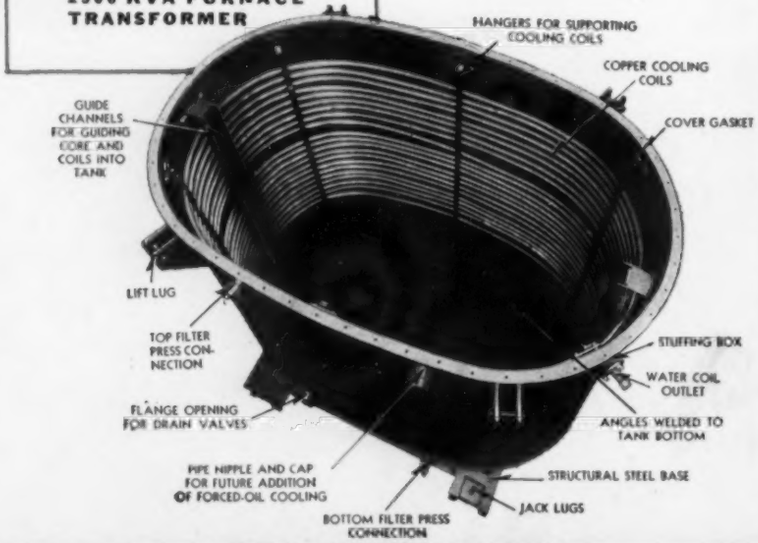


5000 KVA TRANSFORMER
for operating a 15-Ton Furnace



7500 KVA TRANSFORMER
for operating a 30-Ton Furnace

TANK INTERIOR OF 2500 KVA FURNACE TRANSFORMER


HANGERS FOR SUPPORTING COOLING COILS
COPPER COOLING COILS
COVER GASKET
GUIDE CHANNELS FOR GUIDING CORE AND COILS INTO TANK
LIFT LUG
TOP FILTER PRESS CONNECTION
STUFFING BOX
WATER COIL OUTLET
FLANGE OPENING FOR DRAIN VALVES
ANGLES WELDED TO TANK BOTTOM
PIPE NIPPLE AND CAP FOR FUTURE ADDITION OF FORCED-OIL COOLING
STRUCTURAL STEEL BASE
JACK LUGS
BOTTOM FILTER PRESS CONNECTION

**Pennsylvania TRANSFORMER COMPANY**

Pennsylvania TRANSFORMERS

*Furnace Transformer Experts*

PITTSBURGH 12, PENNSYLVANIA

# Personnel News . . . .

**R. F. Miller** has been appointed assistant to vice president, research and technology department, Carnegie-Illinois Steel Corporation, Pittsburgh, Pennsylvania. After graduating from Williams College in 1930, Dr. Miller attended Massachusetts Institute of Technology, where he received a degree of doctor of science in 1934. He was employed as an instructor in the metallurgical department of Yale University from 1934 to 1936, when he began his service with United States Steel at its Kearny, New Jersey laboratories. Dr. Miller came to Pittsburgh in 1943 as development engineer in stainless and alloy steels for the department of research and technology, the position he held at the time of his present appointment.

**M. B. "Speck" Farrar,** formerly district manager in Pittsburgh, Pennsylvania, for National Carbon Company, takes up new duties with the Union Carbide Europa, S. A., Rue de la Coiraterie, 6, Geneva, Switzerland, about July 15, 1948. After graduating from Clemson University, Mr. Farrar started operating in the coal mining territory of Western Pennsylvania for National Carbon Company. From there he went to Birmingham, Alabama as sales engineer and later to Pittsburgh, where he assumed the district managership after a few years of active service as sales engineer.

Mr. Farrar's new duties in Europe will take him into steel plants, chemical plants and all process industries interested in purchasing carbon for blast furnace lining and accessories; electrodes for electric furnaces; graphite; molds; impervious carbon and graphite for use with exchangers; pipe lines; tank linings, etc. His activities in Europe in general will parallel his work in the Pittsburgh district.

**Earl A. Garber** was elected president of Harbison-Walker Refractories Company, succeeding Raymond Willey, retired. Mr. Garber became connected with Harbison-Walker in 1915 at the plant at Harwalk, Ohio. He came east in 1944 as vice president of Northwest Magnesite Company, and general manager of the company plants at Chewelah, Washington, and Cape May, New Jersey. In January 1947 he was elected vice president and general manager of Harbison-Walker, and later that year became vice president and general manager of Louthan Manufacturing Company, East Liverpool, Ohio, upon its acquisition by Harbison-Walker.

American Brake Shoe Company announces the appointment of **Raymond H. Schaefer** as director of research and development. Mr. Schaefer first started with the Brake Shoe Company in 1940 as an assistant foundry metallurgist for the American Manganese Steel division. He became chief metallurgist in charge of metallurgical research and the company's experimental foundry in 1945. A native of Lynn, Massachusetts, Mr. Schaefer attended Carnegie Institute of Technology from which he received the degree of bachelor of science in 1934.

**H. P. Saxer** was appointed superintendent of the blast furnace department, Jones and Laughlin Steel Corporation, Pittsburgh works. **D. L. Hykes** will continue as assistant superintendent of that department and **J. R. McCarney** has been appointed assistant to the superintendent.

**Norman P. Hitchcock** has been appointed assistant superintendent of maintenance (electrical) at the Brier Hill works of Youngstown Sheet and Tube Company, succeeding Louis C. Breetz who retired May 31.

Mr. Hitchcock went to Youngstown, Ohio, as power house repairman in the Campbell plant in 1933 from RCA Victor Company at Camden, New Jersey, where he was a test engineer. Three years later he was made chief electrical inspector at Campbell and in 1940 was transferred to the Brier Hill works as general foreman, nights, maintenance. He received a bachelor of arts degree from Western Reserve and his bachelor of science degree in electrical engineering from Case School of Applied Science.

**Richard C. Horning** was elected to the position of assistant treasurer of the Mesta Machine Company, Pittsburgh, Pennsylvania. Mr. Horning graduated from Shadyside Academy, Pittsburgh and attended Yale University and Carnegie Institute of Technology. His entire business career has been spent with Mesta Machine Company. From 1934 he has served in various departments and was a sales engineer specializing in

R. F. MILLER

M. B. "SPECK" FARRAR

EARL A. GARBER

RAYMOND H. SCHAEFER

BOWSER
ESTABLISHED 1885

lubricating systems

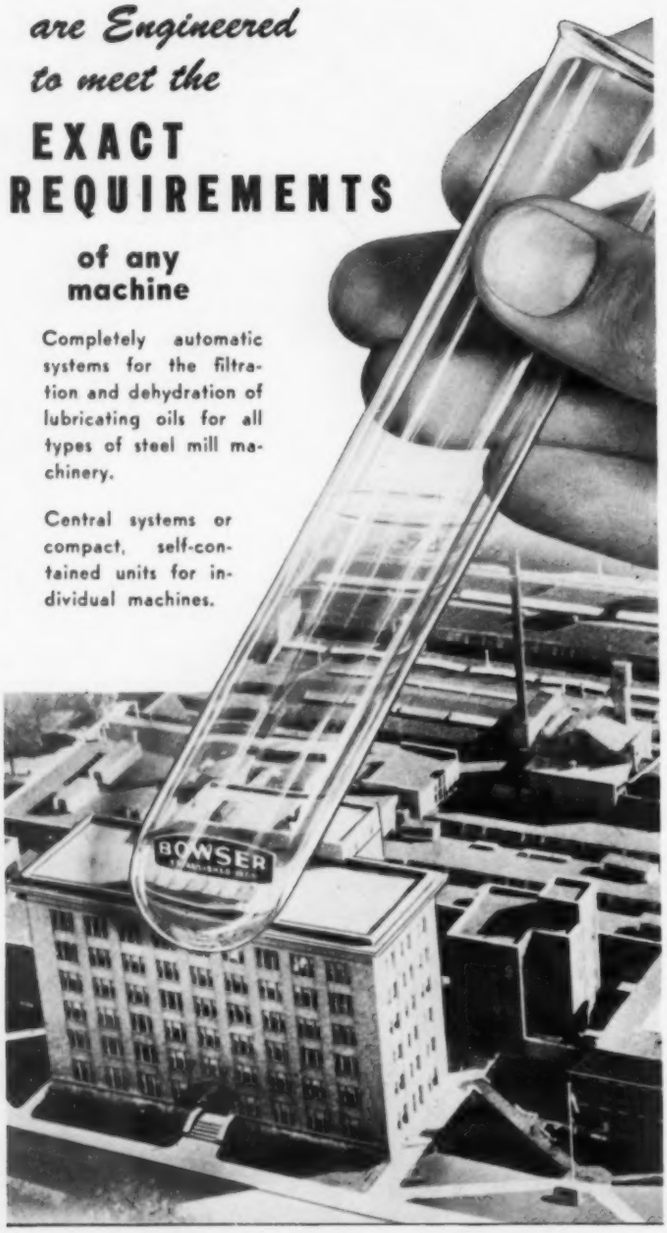
*are Engineered to meet the*

EXACT REQUIREMENTS

of any machine

Completely automatic systems for the filtration and dehydration of lubricating oils for all types of steel mill machinery.

Central systems or compact, self-contained units for individual machines.




BOWSER, INC.
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FORT WAYNE 2, INDIANA

LIQUID CONTROL SPECIALISTS
SINCE 1885

rolls previous to his present appointment. Shortly after the outbreak of the war, he entered the Navy, serving overseas three years with the commission of lieutenant.

**Uri B. Grannis, Jr.** has been appointed manager of equipment sales for the American Brakeblok division of the American Brake Shoe Company. Mr. Grannis has been with Brake Shoe since 1935 and has served in various sales capacities with the company. A native of Chicago, Illinois, he is a graduate of Princeton University in Princeton, New Jersey. He will be located at the division's headquarters in Detroit, Michigan.

**Alfred W. Ward** has been elected chairman of the board of Brooks Oil Company, Cleveland, Ohio. Mr. Ward has been associated with Brooks Oil since 1920 and has been president of the company since 1940. As president, Mr. Ward succeeded his father, A. M. Ward, who served for 44 years in that capacity.

**Fred H. McCurdy** was elected president of Brooks Oil Company, Cleveland, Ohio. Mr. McCurdy joined the company in 1932. He initiated the industrial divi-

FRED H. McCURDY

sion of Brooks Oil and has served as manager of that division and as vice president and director of the company. He is the fourth president of Brooks Oil Company in its 72 years of continuous operation.

W. MORRISON

**W. Morrison** was elected vice president and director

of Brooks Oil Company, Cleveland, Ohio. **Joseph A.**

JOSEPH A. RIGBY

**Rigby** was named manager of engineering and sales.

**Edward R. Hall** was promoted to the position of vice president and assistant general manager, shops division of Koppers Company, Inc. Since August 1, 1946, Mr. Hall has been vice president and works manager of the division which operates the well-known Bartlett Hayward plant in Baltimore, Maryland.

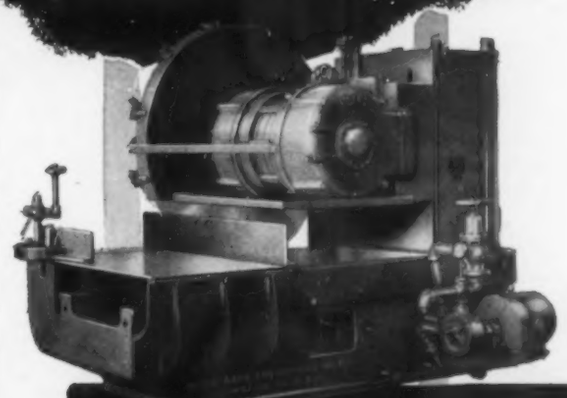
**William P. Fields** was named superintendent, roll shop, at Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania. Mr. Fields graduated from Pennsylvania State College in 1939 with a bachelor of science degree in mechanical engineering. In February, 1939, he started at the Duquesne works as an observer and in 1942 became special engineer. In October, 1946, he was appointed roll designer, which position he held until his recent promotion.

**Edgar M. D. Harold,** formerly superintendent, roll shop, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania, is now assistant superintendent of finishing mills, Crucible Steel Company of America, Midland, Pennsylvania.

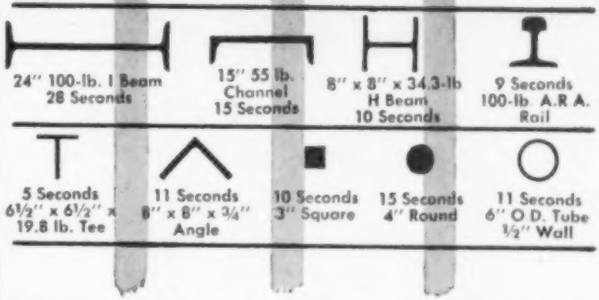
**Dr. Philip J. Wilson, Jr.,** has left Mellon Institute to join the research and development division of his fellowship donor, the Carnegie-Illinois Steel Corporation, Pittsburgh, as a research associate where he will supervise the work on process design. On the Carnegie-Illinois fellowship in Mellon Institute, he held the post of senior fellow since the inception of this fellowship on May 1, 1933. Dr. Joseph H. Wells, who has been on the fellowship since it was founded, will now head its activities.

**Raymond Willey,** president of Harbison-Walker Refractories Company, retired July 1. A veteran of 46 years service with Harbison-Walker, and re-elected president April 19 by the board of directors, Mr. Willey has asked to be relieved of his executive office. He has been president since 1939. He first became associated with the company in 1901 as assistant to the supervisor of magnesite purchases in Budapest, Hungary, where he had been engaged as vice counsel with the United States Consular Service. After completion of the magnesite purchases, he returned to this country where he served in various capacities for Harbison-Walker until


Modern Sawing



with KLING HIGH SPEED FRICTION SAWS




Friction sawing is one of few mechanical processes which employ the heat of friction in a useful manner. It concentrates heat on the material to be severed at a rate which is faster than it can absorb heat. The immediate temperature rise of the contact surface is so great that its strength is reduced considerably lower than that of the colder blade rim. This heated surface is readily removed by the blade and permits complete severing of the material rapidly with no loss of metal from the blade.

Because of its versatile ability to cut many varied structural shapes, as well as solid or hollow bars in any sequence, without change of blade or set-up, one machine can handle a volume of cutting that would otherwise require several separate shears or slow speed saws.

Consult Kling engineers regarding your metal cutting problems. State size of material to be cut. Bulletin No. 9200 giving full particulars and suggestions as to the type and size of saw will be mailed promptly. No obligation.

KLING BROS. *Engineering Works*

Punches; Bar, Angle and Rotary Shears; Combination Shear, Punch and Copers; Plate and Angle Bending Rolls; Heavy Duty Grinders

1324 N. KOSTNER AVENUE, CHICAGO 51, ILLINOIS, U. S. A.

*New*

**FILTER-AIRE for Crane Cabs Removes ALL Smoke and Gases**

*LOW IN COST*

This new Filter-Aire is ideal for cabs of cranes, such as foundry, weld shop, and at many locations in steel and large industrial plants where mechanical refrigeration is not required and atmospheric conditions are bad due to smoke and waste gases.

Only 60" x 14" x 26", the Filter-Aire fits easily in the conventional type of cab (enclosed) against back wall. The unit is available for AC or DC operation.

The Filter-Aire is equipped with mechanical screen filter on the fresh air intake. The air then passes through the electro-static filter (capacity, 350 cfm) which clears the air of all smoke and vapors. Next the air filters through a bank of 12 activated carbon canisters which remove waste gases and fumes. The result is clean, pure air regardless of the surrounding atmospheres. Furthermore, the unit is equipped with an electric heater for maintaining comfortable temperatures in winter — the amount of heat being controlled by an automatic thermostat. An adjustable damper regulates the amount of outside air taken into the unit.

Providing rapid circulation of air in the cab, the Filter-Aire produces maximum cooling effect without refrigeration. The unit is fully self-contained; filters are easily accessible for servicing. Low priced — less than $1,000. Send for folder.

**THE LINTERN CORPORATION**

54 LINCOLN AVENUE BEREA, OHIO

1913 when he came to Pittsburgh as assistant to the vice president in charge of operations. In 1917 he was elected a director, and in 1929 was named vice president in charge of operations.

**Arthur E. Currier** has recently joined the research department of Harbison-Walker Refractories Company, Pittsburgh, Pennsylvania. Dr. Currier received his bachelor of ceramic engineering degree from Ohio State University in 1940 and did graduate work at the Ohio State Experiment Station on "The Use of Domestic Kyanite," a project sponsored by Johns-Mansville. After four years with the U. S. Army Engineer Corps, he returned to the Ohio State Experiment Station where he worked on a U. S. Potters Association Fellowship, studying the use of fluxes in semi-vitreous white ware bodies.

**John K. Hodnette** was elected a vice president of Westinghouse Electric Corporation. Mr. Hodnette will retain his post as manager of the company's transformer division, a responsibility he assumed in 1946. He has been with Westinghouse since 1923, the year following his graduation as a mechanical engineer from Alabama Polytechnic Institute.

He started at the company's East Pittsburgh works

**JOHN K. HODNETTE**

and in 1925 was assigned to transformer engineering and design at the Sharon plant. One of his outstanding achievements in this field was development of a power distribution transformer completely self-protected against lightning and electrical overloads. Mr. Hodnette became engineering manager of the transformer division in 1940. He was born at Notasulga, Alabama, in 1902.

**Berle Ludwig,** former ship yards superintendent in Mobile, Alabama, is now general superintendent at Kerrigan Iron Works, Inc., Nashville, Tennessee.

**Henry Wysor,** metallurgical engineer on the staff of the operating vice president, Bethlehem Steel Company, retired from active service on July 1. Mr. Wysor, a graduate from Virginia Polytechnic Institute, had been with Bethlehem since 1918. Prior to that time he taught at Lafayette College for 14 years, the last six years serving as head of the department of metallurgy. He will be succeeded by **John K. Killmer,** who has been with Bethlehem in various capacities since his graduation from Lehigh University in 1923. During the last year Mr. Killmer served for about three years in the

steel division of the War Production Board, as chief of the Alloy Steel Branch and as assistant director of the division.

**L. D. Litsey** has been appointed Chicago area representative for worm gear speed reducers for the De Laval Steam Turbine Company, Trenton, New Jersey. Mr. Litsey has had wide experience in the application of industrial equipment with the Standard Seamless

L. D. LITSEY

Tubes Company, the Wykoff Drawn Steel Company and the Bartlett-Hayward division of Koppers Company, and later with John Waldron Corporation as sales engineer and manager of the company's coupling division. Headquarters for Mr. Litsey are maintained at the Litsey Equipment Company, 6459 North Sheridan Road, Chicago, Illinois.

**Russell C. Fancher** was appointed as sales representative for U. S. Stoneware Company in the Detroit area. Mr. Fancher will work out of the newly opened office at 6432 Cass Avenue, Detroit, Michigan.

**Walter E. Bisler** will represent Flexible Underground Pipe Cleaning Company and Flexible Sewer-Rod Equipment Company in the Western Pennsylvania and West Virginia area. His headquarters will be

WALTER E. BISLER

at 909 North Homewood Avenue, Pittsburgh, Pennsylvania. For the past four years, Mr. Bisler has been doing cleaning service development work for Dowell, Inc.,


LOOK TO THE FUSE LEADER FOR PRODUCTION PROGRESS

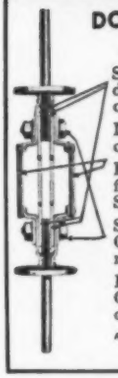
Cool!

THE FIRST COOL OPERATING FUSE . . . DESIGNED BY WARE

WARE HI-LAG Renewable FUSES

Cool Facts No. 2

DOUBLE BRIDGE ASSEMBLY



Spring tension, double contact area on link.

Links centered in all casings.

Double Fibre Bridge for Alignment and Strength.

Screws Locked—Only one wrench needed.

Insert either end in Casing. Minimum of parts.

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**The Fuse That Science Built Cool to Prevent Excessive Heating During Heavy Current Loads and Long Service**

When you make that next fuse installation, consider the World's Best and Coolest Operating Fuse—try WARE HI-LAG.

You will then see for yourself how the WARE HI-LAG stays cool under conditions that ordinarily cause overheating—you will see why its good business to standardize on a product that ends costly delays—needless production shutdowns and interruptions.

There's higher lag for motor starting overloads—stronger lag for operating current surges—lower contact resistance, reduced heating and larger and stronger terminal connections. The double-bridge assembly at left is another cool construction feature, helping to lower contact resistance and excessive heating.

*Write for Fuse Booklet No. 4460 giving all features, sizes and details.*

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SAVE TIME
On Every Job
WITH A
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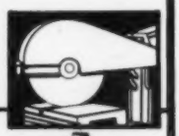
Cuts
● FIRE BRICK
● BUILDING TILE
with ● CONCRETE BLOCKS

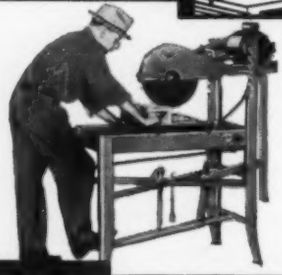
AMAZING Speed AND Accuracy

● You'll be amazed how quickly and easily you can cut virtually any special length or shape from the hardest masonry materials. Clippers save time — save material, assure better workmanship on every job.

Cuts DRY

Clipper's exclusive design is guaranteed to provide the highest economy with most rapid cutting speed. With or without foot pedal control.





Cuts WET

No dust. With foot pedal control or without. You can set the cutting head in locked position. The hardest materials cut with ease.

FAST and FLEXIBLE

The New Model HD-48 Clipper cuts dry just exactly the same as regular Clipper Masonry Saws.. and for Dustless masonry cutting just turn on the circulating system and slice thru the hardest materials. Proven by ten years use throughout the world. Guaranteed to provide the fastest cuts with lowest cost.

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Yes . . . with a Clipper it's easy to slice thru Brick, Tile, Concrete, Glass, Marble, Porcelain or any kind of Refractories . . . Straight cuts, Angles or Mitres. CLIPPERS FOR EVERY JOB — Priced as low as $195. Write for Catalog Today!

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PHILADELPHIA CLEVELAND ST. LOUIS AUSTIN, TEX.

and Pittsburgh Pipe Cleaner Company in the eastern seaboard area.

**E. E. Bauer** has been appointed central district sales manager of Peerless Pump division, Food Machinery Corporation, located at 4554 North Broadway, Chicago, Illinois. Mr. Bauer was formerly centrifugal pump sectional sales manager for the Peerless division. As district manager, Bauer will now supervise the sales of both the Peerless horizontal and vertical lines and other pumps of the company's manufacture. **Frank W. McCann** has been named to the position formerly held by Mr. Bauer. Mr. McCann will be located at the Peerless plant at Quincy, Illinois.

**William F. Bowers, Jr.,** was appointed assistant open hearth superintendent, iron and steel division, Kaiser Company, Inc., Fontana, California. At the Fontana plant since March, 1947, Mr. Bowers formerly worked for Carnegie-Illinois Steel Corporation for 10 years. He received his degree in metallurgy from the University of Alabama, and did graduate work in civil engineering at the University of Pittsburgh.

## *Obituaries*

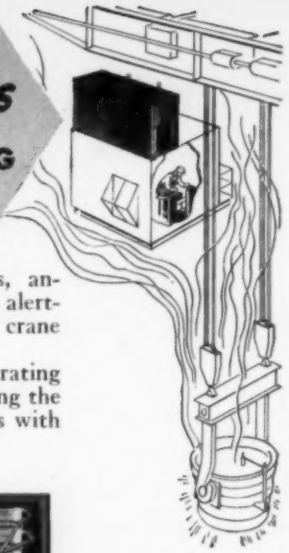
**Charles E. Underwood,** 63, superintendent, coke oven division, Bethlehem plant, Bethlehem Steel Company, since 1916, died June 13 in St. Luke's Hospital, Bethlehem, Pennsylvania. Mr. Underwood had been in the coke and gas business since graduating from high school in 1901. Born in Baston, Nova Scotia, December 27, 1884, he received his education in the public schools and high school of Everett, Massachusetts. In 1901 he started working as a laborer for the New England Gas and Coke Company.

In 1904 Mr. Underwood moved to Sharon, Pennsylvania, working as exhaust house engineer and later as battery foreman in the coke plant of United States Steel Corporation. After a short interval from 1907 to 1909 in other employment, he returned to United States Steel and filled various positions about the coke plant until 1913, when he was made superintendent of the coke works at Joliet, Illinois.

In 1915 he accepted a position with a new municipal gas works at Joliet, Illinois, but he left early in the following year to manage an independently operated coke plant in Glassport, Pennsylvania. In the latter part of 1916 he was appointed superintendent of the coke works of Lehigh Coke Company in Bethlehem. When this plant was taken over by Bethlehem Steel Company he was first its assistant superintendent and then, on October 15, 1916, he became superintendent, the position he has held since.

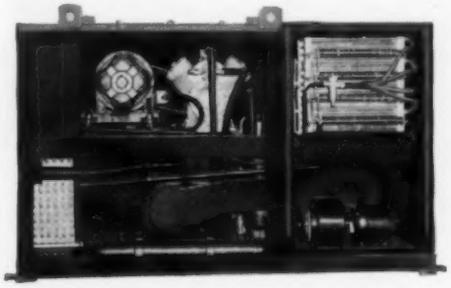
**John Edwards,** recently retired as assistant treasurer of Mesta Machine Company, died in his Pittsburgh suburban home, 1046 Washington Road, Mt. Lebanon, June 20. He had been ill for some time. Mr. Edwards was born in Stourbridge, Worcestershire, England, January 1, 1875. He was a schoolmaster in the Old Swinford Hospital school. He came to America in 1907, and after a few months as a clerk for a railroad went to Mesta, where he worked for more than forty years. He has occupied the position of assistant treasurer since 1925.

## DRAVO CRANE CAB COOLERS REDUCE OPERATING HAZARDS



● Excessive heat, obnoxious fumes, annoying dust and moisture reduce the alertness and efficiency of your hot-metal crane operators.

● You can eliminate these crane operating hazards by completely air conditioning the cabs on all types of hot-metal cranes with Dravo Crane Cab Coolers.



*Completely self-contained Dravo Crane Cab Cooler requires electrical connection only.*

**DRAVO CORPORATION**

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*Sales Representatives in Principal Cities*

DRAVO

## We asked a few Operators how they are doing with ANGLE FLOW TUYERES

U. S. Pat. 2,124,437

Tuyere at top-center of illustration is Angle Flow type with refractory nose.

### Here's What They Reported . . .

Increased requests for the Angle Flow Tuyere, both with and without refractory nose, prompted us to check current results with angle flow installations. These operators enthusiastically reported greatly improved conditions, reduced burning after a switch to Angle Flow Tuyeres.

With tuyere pointed down (towards six o'clock) one operator reports his tuyere life increased from 24 days on conventional type to 100 days with refractory nose Angle Flow Tuyeres. Another who was getting from 30 to 35 days on a conventional type had had Angle Flow units with refractory nose in operation for 60 days and they still remained in the furnace. A third operator stated that he had been burning certain tuyeres nearly every day and that Angle Flow Tuyeres had apparently corrected this condition.

Other reports equally favored Angle Flow Tuyeres. There is every indication that this tuyere design, in Falcon quality casting, is capable of eliminating many troublesome, costly burning problems. Certainly they warrant a trial installation. Falcon is licensed to produce the Angle Flow Tuyere under U. S. Pat. No. 2,124,437 and is prepared to offer prompt delivery.

TELEPHONE COLLECT - 3-4355

**FALCON BRONZE CO.**

YOUNGSTOWN 3, OHIO

Established 1890 • Incorporated 1895

## Want to preserve the life of Ball and Roller Bearings?

### LUBRICATE WITH NON-FLUID OIL

Remember that "the cleanest bearing is only as clean as the lubricant used in it" and you'll remember to use NON-FLUID OIL. NON-FLUID OIL fully measures up to the strict specifications laid down by anti-friction bearing manufacturers.

With its unique "built-in" qualities, NON-FLUID OIL *stays alive longer* than ordinary greases, retaining its high lubricating properties until entirely used up — assuring long, trouble-free bearing life at lowest maintenance cost.

Write for Bulletin 506AISE and free, testing sample of NON-FLUID OIL

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*NON-FLUID OIL is not the name of a general class of lubricants but is a specific product of our manufacture.*

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# DATE LINE DIARY...

**June 1**

▲ The Federal Power Commission today granted the request of Texas Eastern Transmission Corporation for a temporary certificate authorizing construction of new facilities which will increase the natural gas delivery capacity of its Big Inch and Little Big Inch pipe lines to 508,000,000 cubic feet per day by the beginning of 1949. This will be an increase of 75,000,000 cubic feet daily over the delivery rate originally planned by the company by the end of 1948.

▲ The operating rate of steel companies having 94 per cent of the steel capacity of the industry will be 96.0 per cent of capacity for the week beginning June 1, equivalent to 1,730,400 tons of steel ingots and castings, compared to 1,744,800 tons one week ago.

**June 3**

▲ Freight cars delivered during May totaled 9,192, of which 6,651 were built by car builders and 2,541 were built in railroad shops. Cars on order total 127,681.

**June 4**

▲ Electrical wire manufacturers are now producing wire for homes and commercial buildings at the record rate of six billion feet per year. Most of the wire is made of copper insulated with rubber. The shortage of copper has stimulated interest in aluminum wire, which is plentiful, cheaper and lighter in weight.

**June 5**

▲ In a report of the Munitions Board just issued, it is indicated that manufacturers must set up their war mobilization conversion plans if they shall wish to obtain materials and manpower in the next war.

**June 6**

▲ According to a quarterly survey made by the Securities and Exchange Commission and the Department of Commerce, it is estimated that American business will spend $18,700,000,000 during 1948 for new plants and new equipment.

**June 7**

▲ According to the National Coal Association, total 1948 production of coal through May 22 was 215,498,000 tons, compared with 251,650,000 tons for the corresponding period of 1947.

▲ The operating rate of steel companies having 94 per cent of the steel capacity of the industry will be 96.1 per cent of capacity for the week beginning June 7, equivalent to 1,732,200 tons of steel ingots and castings, compared to 1,730,400 tons one week ago.

**June 11**

▲ In 1947 the steel industry of the United States sent more finished steel to the rest of the world than in any other peacetime year. The Department of Commerce reported that a total of 6,543,085 tons were shipped.

**June 12**

▲ The National Safety Council revealed that industry had a better safety record in 1947 than in 1946. The number of disabling injuries per 1,000,000 man-hours was 13.26 in 1947 for a reduction of 10 per cent from the previous year. The iron and steel products industry was better than last year, with a rate of 13.01 disabling injuries per 1,000,000 man-hours and the steel industry itself ranks number 3 in the group with a frequency rate of 6.08 disabling injuries per 1,000,000 man-hours. The severity of injuries measured in days lost per 1000 man-hours was 1.23 for all industries, with iron and steel products having a rate of 0.81 and the steel industry itself having a rate of 1.60.

**June 13**

▲ Iron and steel export shipments for the first quarter of 1948 were 16 per cent below the corresponding average for 1947.

**June 14**

▲ The conference between steel industry representatives and the Munitions Board indicated that military planners will probably not insist on the large expansion asked for by some government economists provided that non-essential users are curbed if necessary.

▲ The operating rate of steel companies having 94 per cent of the steel capacity of the industry will be 96.0 per cent of capacity for the week beginning June 14, equivalent to 1,730,400 tons of steel ingots and castings, compared to 1,732,200 tons one week ago.

**June 15**

▲ According to the American Iron and Steel Institute, the payroll for the iron and steel industry for the first four months of 1948 was $699,278,000, or an increase of $84,000,000 over the corresponding period of 1947. This was in spite of the fact that in April, employment and earnings declined because of the coal miners' walkout.

**June 16**

▲ Inland Steel Company announced the letting of a contract to the American Ship Building Company of Cleveland, Ohio, for the construction of a new ship, which it is expected, will be the largest and fastest ore carrier on the Great Lakes. This ship, which is 668 feet long, is estimated to carry 20,000 gross tons of cargo at its intermediate draft. It will have 7000 shaft horsepower, and when fully loaded will have the speed of 16 miles per hour. Delivery is expected before the navigation season of 1950.

**June 18**

▲ According to the American Iron and Steel Institute, the iron and steel industry used 20,016,000 gross tons of purchased scrap in 1947 for a new record.

**June 19**

▲ It appears now as if the Koppers Company, Inc., the Arthur G. McKee Company, and Great Britain's International Construction Company, Ltd., may handle the big expansion program of India's steel industry provided the program is financed and approved. One of the big problems in this expansion is whether a single 1,000,000 ton steel plant at an estimated cost of $480,000,000 should be built, or whether two 500,000 ton plants at a total estimated cost of $450,000,000 should be built.

**June 20**

▲ It appears as if the steam locomotive is now on its way out and one sign of this trend is the closing down by the American Locomotive Company of its steam department because of no orders.

**June 21**

▲ The operating rate of steel companies having 94 per cent of the steel capacity of the industry will be 96.2 per cent of capacity for the week beginning June 21, equivalent to 1,734,000 tons of steel ingots and castings, compared to 1,730,400 tons one week ago.

**June 22**

▲ A new steel company called the Penn-Ohio Steel Corporation has been formed by former officials of the Empire Steel Corporation, who have leased the naval reserve steel plant at Birdsboro, Pennsylvania. They plan to produce ingots within 30 days. The plant includes two 50 ton basic open hearth furnaces and output should be 6000 tons a month.

▲ L. Abbett Post, executive vice president of the American Institute of Steel Construction pointed out in an address that a slackening off of industrial building, particularly in the Chicago area, is noticeable. Some of this is due to rising costs but in other cases, it means that the industrial plant needed for postwar business has been built.

**June 23**

▲ The Texas Gas Transmission Corporation filed today an application asking authority to construct a new 26 inch, 840 mile pipe line from Texas to Ohio. The additional gas will go to consumers and utility companies in the Kentucky, Ohio and Pennsylvania areas.

**June 24**

▲ The General Electric Company increased list prices of a number of household appliances and several industrial equipment items from 5 to 12 per cent. This rise was due to higher labor costs because of their recent wage increase granted employees, increased freight rates and material costs.

▲ Thomas E. Dewey was nominated by the Republican party at the convention in Philadelphia as their candidate for president of the United States.

**June 25**

▲ Governor Earl Warren of California was nominated by the Republicans as their candidate for vice president of the United States, thus forming one of the strongest pair of candidates that could possibly have been devised.

**June 26**

▲ In a rider to the selective service act, Congress voted the president mandatory allocation powers over steel for military uses. This act gives the president authority to seize plants and fine and imprison steel producers who do not comply with the order.

**June 28**

▲ The stock market dropped one to four points in one of the worst overall declines of the year.

▲ The operating rate of steel companies having 94 per cent of the steel capacity of the industry will be 95.2 per cent of capacity for the week beginning June 28, equivalent to 1,716,000 tons of steel ingots and castings, compared to 1,734,000 tons one week ago.

**June 29**

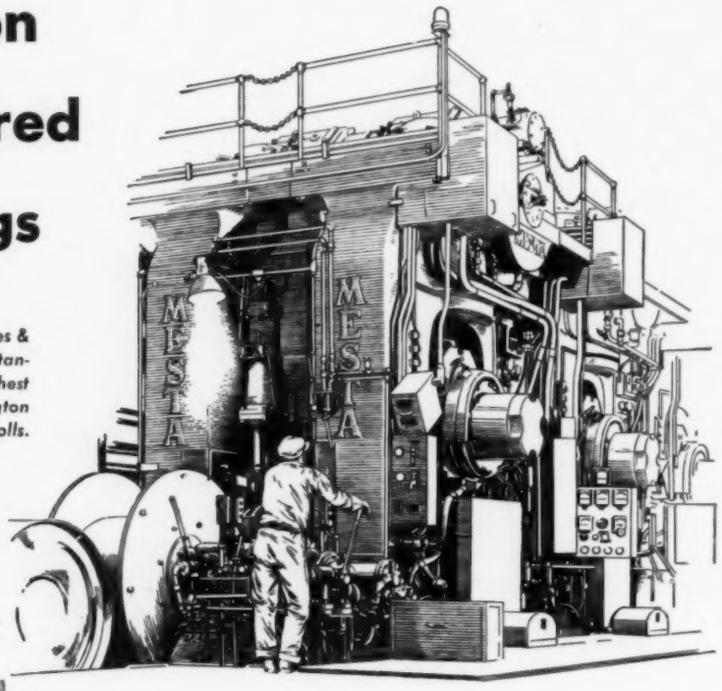
▲ The Harbison-Walker Refractories Company announced an increase in brick prices effective July 6. This increase would particularly affect the steel industry which is the largest consumer of the company's products.

▲ The 30 millionth Bell system telephone was installed in the town of Marshalltown, Iowa. This installation came 72 years after the invention was perfected. Although the first 10,000,000 telephones were not installed for 45 years, it has taken less than 6 years to install the third 10,000,000.

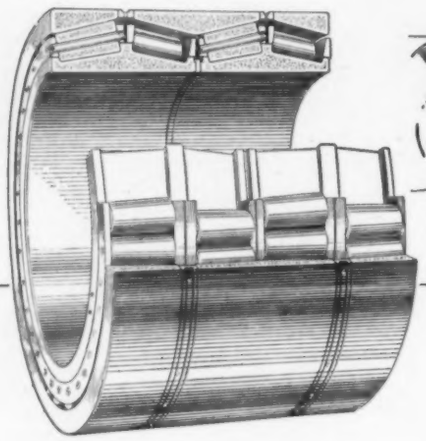
**June 30**

▲ Blaine S. Smith, president of Universal Atlas Cement Company announced that effective July 7, his company will abandon its method of selling cement which it has used continuously for more than 40 years. In accordance with the recent decision of the United States Supreme Court sustaining a cease and desist order of the Federal Trade Commission, Universal Atlas will adopt the method of selling cement at prices which reflect full transportation charges from shipping point to destination.

# Fastest Rolling Mill Sets Tonnage Records with Torrington Four-Row Tapered Roller Bearings




*Built by Mesta Machine Company for the Jones & Laughlin Steel Corporation, this five-stand tandem cold strip mill attains the world's highest speed production with the help of Torrington four-row Tapered Roller Bearings on work rolls.*



**. . . rapid acceleration and long runs with minimum time-out for maintenance are advantages of high-capacity Torrington Bearings.**

COLD-REDUCTION of steel strip at 6,250 fpm is the world's record speed, attained by the five stand tandem cold strip mill built by Mesta for the Aliquippa Works of the Jones & Laughlin Steel Corporation. The strip mill work rolls are equipped for high speed and long service life with Torrington Tapered Roller Bearings.

The tremendous load-carrying capacity, low starting and running torque and long service life of these Torrington Bearings help assure the long runs, high speeds and uninterrupted operation that mean greater uniformity in gage and quality of finished strip. The rapid acceleration—from 300 to 4500 fpm in six *seconds*—not only reduces to a minimum the amount of off-gage strip which results from speed changes, but also reduces power requirements.

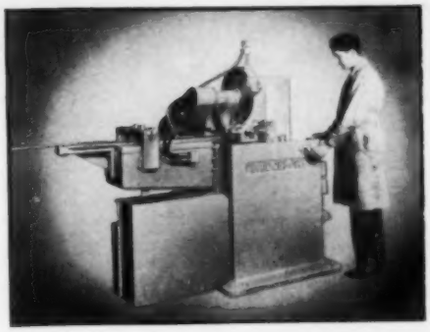
The specialized experience of Torrington's engineers is available in applying these and other bearings in the Torrington line to work rolls, back-up rolls, screw downs, edgers, shears, table rolls, pinion stands and similar equipment. Call or write the nearest Torrington office.

THE TORRINGTON COMPANY
South Bend 21, Ind. • Torrington, Conn.
*District Offices and Distributors in Principal Cities*

# TORRINGTON BEARINGS

**SPHERICAL ROLLER · TAPERED ROLLER · STRAIGHT ROLLER · NEEDLE · BALL · NEEDLE ROLLERS**

(*Continued from page 100*)



**This new machine is designed for high speed cut-off of stock up to 2 in. square to lengths ranging from ¼ in. to 12 in.**

actuated by a hydraulic cylinder which feeds the wheel in and out of the cut. The hydraulically operated feed mechanism is synchronized with the cutting head and automatically feeds a predetermined length of stock into position where it is gripped by a holding vise. After the cut has been completed the wheel withdraws, the feeder returns to normal position and the cycle is repeated automatically until the stock is exhausted or the machine is stopped by the operator.

Fully automatic operation, high production rate and cuts held to close tolerances are a few of the features of Bridgeport Model 51 which the manufacturers feel will fill an outstanding need in industry the country over.

## TWO NEW BLAST FURNACES OPERATING IN CHICAGO

U. S. Steel's postwar modernization and improvement program in the Chicago district moved into high gear June 23 when the first iron was made by the second of two giant blast furnaces at the South Chicago plant of the subsidiary Carnegie-Illinois Steel Corporation. Both of the new blast furnaces rank among the world's largest and have a daily capacity exceeding 1500 tons of iron.

The two blast furnaces at the South Chicago plant are No. 11, replacing the smaller dismantled No. 7, and No. 12, replacing No. 9, also a much smaller installation. Completion of No. 12, preceded several weeks ago by No. 11, gives the plant an increase of 560,000 tons of iron annually to make the plant's yearly iron capacity total 4,200,000 tons.

The furnaces are part of United States Steel Corporation's $775,000,-


# Where is the safest position for a lifting magnet's weld—

• Operating men who have seen the beating a magnet takes in service know that TOP OF THE MAGNET is the safest place for a weld. *Only new Ohio PROTECTO-WELD Magnets offer you this advantage!*

They're built to withstand harder knocks day in and day out for years. Outer ring and top plate are welded together ON TOP OF THE MAGNET. This protected weld retains its shape, is never dented in. The weld can be turned down for magnet disassembly without cutting away outer ring . . . *without destroying outer pole.*

For extra years of low-cost operation, invest in Ohio PROTECTO-WELD Magnets. They operate cooler . . . lift more uniformly over extended periods of operation . . . last longer. Sizes include 39, 46, 55 and 65-inches diameter. For details, write today to Ohio—*leader in magnetic materials handling.*

*Ohio is also a leading name in the small motor industry*

Ohio MAGNETS

THE OHIO ELECTRIC MFG. CO.

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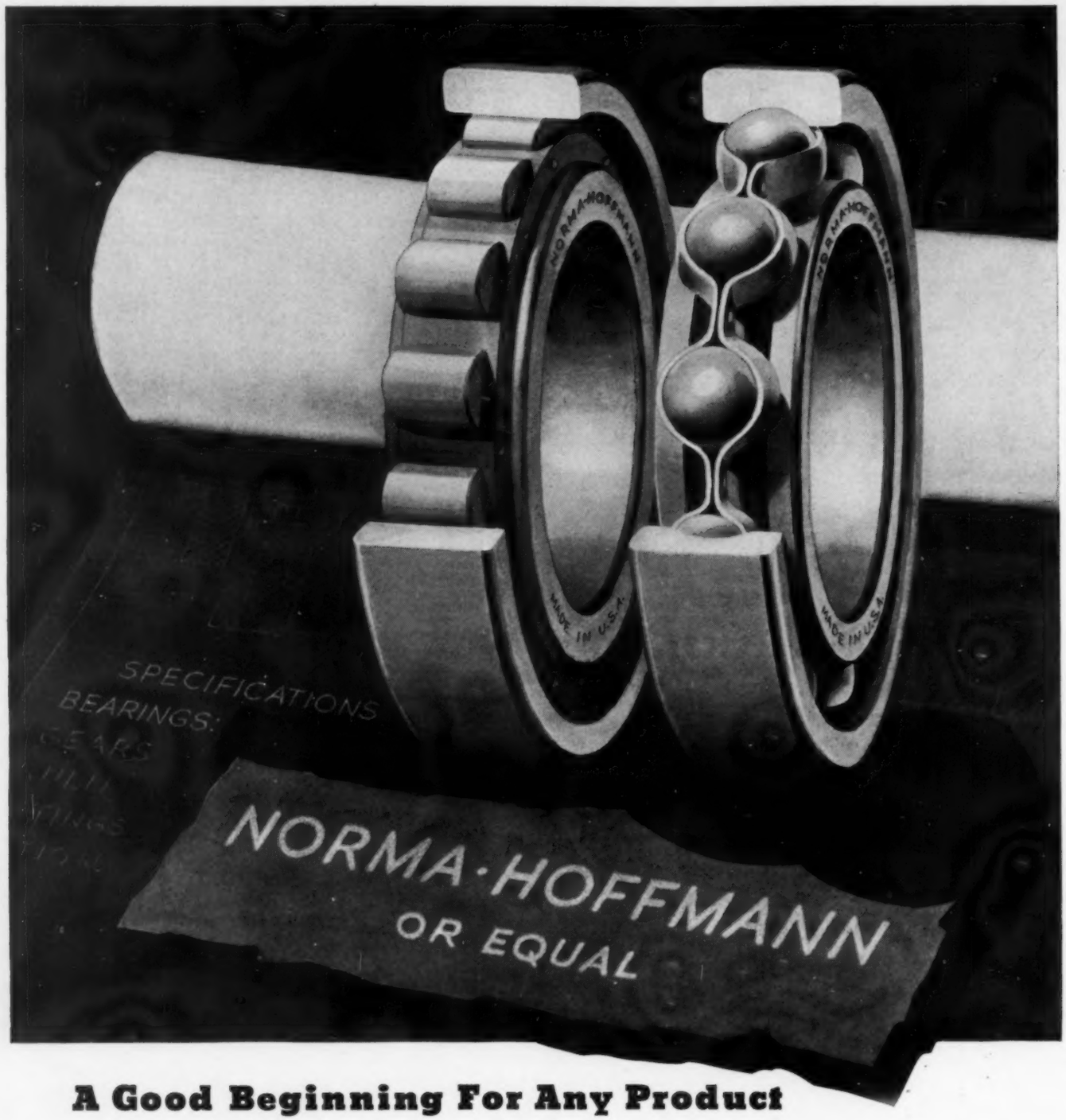



## A Good Beginning For Any Product

Here's why "Norma-Hoffmann or equal" is found on thousands of blueprints embracing all types of equipment. It results from designers' preference for bearings that have earned a reputation over the past 30 years for *precision* and *quality*.

And with good reason! These bearings provide ruggedness, dependability, long life and low upkeep. They assure minimum cost per bearing-year of service. Their accuracy and built-in high antifriction characteristics improve product performance. While the wide range of choice . . . 108 distinct series, over 3,000 sizes . . . makes selection easy.

**NORMA-HOFFMANN**
*Precision*
**BEARINGS**
BALL · ROLLER · THRUST

NORMA-HOFFMANN BEARINGS CORPORATION, STAMFORD, CONNECTICUT • FIELD OFFICES: New York, Chicago, Cleveland, Detroit, Pittsburgh, Cincinnati, Los Angeles, San Francisco, Dallas, Seattle, Phoenix

000 development program in which virtually all operations, from ore and coal mines to sales offices, are sharing from coast to coast. Other improvement projects in the Chicago district, which are underway and to be completed as rapidly as possible, include the following:

1. Increase in the cold rolled strip and tin plate productive capacity at the Gary, Indiana, sheet and tin mill, also a Carnegie-Illinois plant, scheduled for completion during the fourth quarter this year.

2. Additional tube-making facilities at the Gary works of National Tube Company, scheduled for completion in the first quarter of 1949.

3. A new stainless steel wire mill at Waukegan, Illinois works of American Steel and Wire Company, scheduled for completion during the third quarter this year.

Supplementing the preceding projects in the Chicago district, the corporation elsewhere is pursuing a broad and continuing program of replacements and improvements in its iron, coal, coke and steel-producing facilities.

## CRANE CAB CONDITIONERS FOR STEEL PLANTS

One of the four types of Lintern "Aire-Rectifiers" is shown in the accompanying illustration. This unit, for cabs of 200 to 350 cu ft, is extensively used on soaking pit cranes and for other tough applications. Among those companies using this unit are Carnegie-Illinois Steel Corporation. Jones and Laughlin Steel Corporation, National Tube Company, Inland Steel Company, Youngstown Sheet & Tube Company, Allegheny Ludlum Steel Corporation, Ford Motor Company, and Weirton Steel Company.

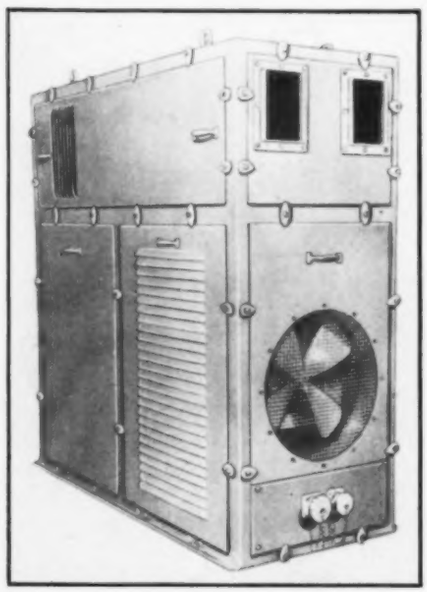
"Aire-Rectifiers," according to Lintern Corporation, soon repay their cost in improved personnel relations and increased manpower efficiency; equipped with oversize air-cooled condenser, they operate day after day, through the hottest summer weather, with low service requirements.

They are usually located on the footwalk above the cab, but in the case of soaking pit and stripper cranes on a platform level with or higher than the cab. They hold properly insulated cabs at a cool 85 F and relative humidity of 30 to 50 per cent, with an ambient temperature of 170 F, without excessive head pressures or wear on the machine.

All models of these conditioners are completely self-contained and immediately available for use regardless of temperature or season. They give trouble-free constant service without frequent inspection.

The model shown may be seen in Lintern Corporation's booth at the Iron and Steel Exposition, September 28 through October 1.

**This crane cab conditioner will be on view at the Iron and Steel Exposition.**



## INTRODUCE NEW LINE OF CENTRIFUGAL PUMPS

Centrifugal pumps with a wide range of capacities and heads have been added to the Bowser, Inc., line of liquid control equipment for the handling of most liquids. Single and two-stage units ranging from ¼ to 75 hp and from 10 to 2500 gal per min, including self-priming types, are suitable for a variety of applications and for viscosities up to 8000 SSU.

Four models are available for immediate delivery: (1) Close-coupled with common shaft—two feet under pump and two under motor; (2) Close-coupled with pump mounted on extended motor shaft and pump adapter—four feet under motor; (3) Pump mounted on base plate, with or without motor and flexible coupling; (4) Self-priming pump mounted on base plate, with or without motor and flexible coupling.

## SCRAP FROM SKULLS

**A new source of scrap was found by one steel mill in its accumulation of 15,000 tons of skulls and buttons. How this good usable scrap could be economically cut to charging-box size was demonstrated by tests made in co-operation with Linde Air Products Company. Skulls, such as the one illustrated, were cut with the "Oxweld C-45" oxy-acetylene blowpipe to sizes convenient for charging into the furnace. Larger skulls, four to six feet in thickness — too thick for oxy-acetylene cutting without some reduction in size were first pierced by conventional lancing techniques, and then split in half by blasting. Total costs to the steel mill averaged less than $5.00 per ton. Because of the economy and ease of operation, reclamation of all skulls has become standard practice at this mill.**

## SHEET AND TUBE COMPANY CONTROLS MATERIAL FLOW

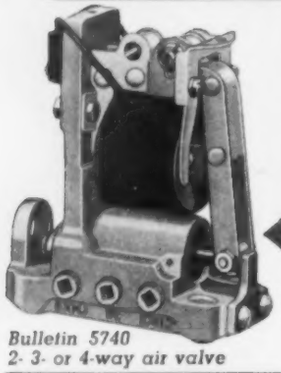
Efficiency in any mass production operation depends upon a steady, controlled flow of materials between each phase of production. Applying mass production techniques to the manufacture of bulky, heavy products only serves to emphasize the importance of gearing materials handling functions to match the productive efforts of manpower and machinery. At the Campbell works of Youngstown Sheet and Tube Company, the problem of setting up a modern handling system, capable of moving heavy loads quickly and easily, was solved by the introduction of the giant Towmotor "Model LT-90" fork lift truck.

These powerful, flexible units, some

(*Please turn to page 126*)

# CLARK SMALL ITEMS • BIG PERFORMERS SMALL IN SIZE

## SUCCESSFULLY APPLIED IN HEAVY INDUSTRIES

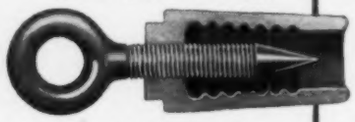


*Bulletin 5740*
*2- 3- or 4-way air valve*

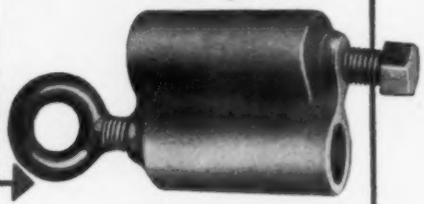
● Pictured are a few of the many small devices made by CLARK for use in heavy industries. Sturdily built, they perform successfully under tough and rugged conditions.

Bulletin 5740 Air Valves ⅜" size (magnet operated—not solenoid) 100 lbs. sq. inch maximum air pressure; 110 to 550 Volt A.C. 25 to 60 cycle. Typical successful operation —reversing valves in open hearths.

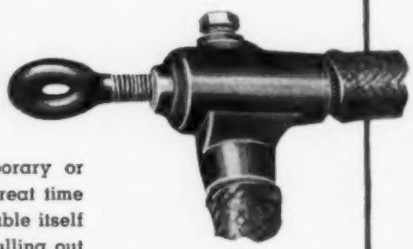
*BULLETIN 105*
*SCREWJACK CLAMPS*



*Single Barrel Clamp with Eye Bolt*



*Double Barrel Clamp Barrels Parallel*



*Double Barrel Clamp Barrel at Right Angles*

Bulletin 105 Screw Jack Clamps are offered in a variety of forms and sizes for making dead ending connections, and taking off taps in main and feeder stranded power cables. One type is specially designed for making temporary or permanent cable splices. Great time savers; stronger than the cable itself —wire will break before pulling out of socket. Used extensively by many steel plants.

*Bulletin 101*
*Foot Switch with Latch*

Bulletin 101 Foot Switches are available for either horizontal or vertical mounting. Right or left hand operation optional, and only a screw driver is needed to change. Made with or without latch. A number of different enclosures are available providing 1- 2- or 4-poles. For applications where hands must be free, such as grinders, and machine tools.

Bulletin 100 Push Button (ROUGHNECK) in a cast enclosure, is built for operation by hand, foot, or tongs. You can punch it, hit it, or kick it, without damage, as all shock is absorbed by the cast case. Frequently used as a Foot Switch.

*Bulletin 100*
*Roughneck Push Button*

*Bulletin 7313*
*Electronic Timer*

Bulletin 7313 Electronic Timer provides extremely accurate and easily adjusted time intervals in Electric Control circuits to open or close a contact an adjustable time after a separate actuating device functions. Timing range of 20 to 1 with stepless adjustment. Rapid recovery for next operation after conclusion of timing cycle. One widely used and commonly available long life radio tube.

**CONSULT OUR NEAREST DISTRICT OFFICE OR WRITE FOR FULLY DESCRIPTIVE BULLETINS**

**THE CLARK CONTROLLER CO.**

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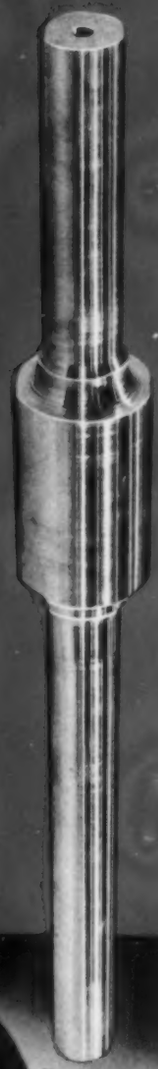
# Stainless Steel Forgings by HEPPENSTALL

SHAFTS, discs, bucket wheels, rolled and forged rings represent a few of the stainless steel forgings manufactured by Heppenstall. For any stainless steel shapes you may require, the combination of Heppenstall's own steel and the quality of Heppenstall workmanship is your assurance of fine forgings.

All standard stainless steel grades are available at Heppenstall. And if you need stainless steel forgings of special analysis —for unusual durability, strength, or hardness—our metallurgists will be pleased to help solve your problems. Contact Heppenstall Company, Pittsburgh 1, Pa.



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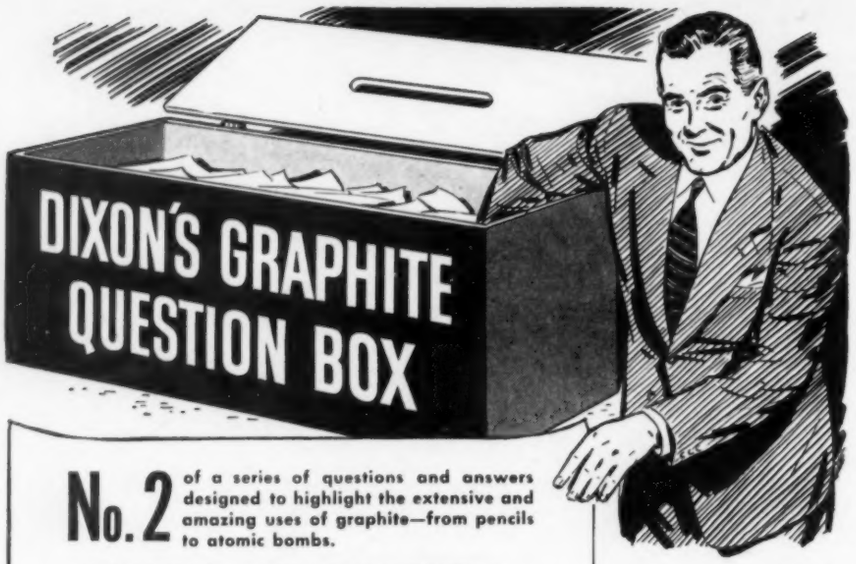



**No. 2** of a series of questions and answers designed to highlight the extensive and amazing uses of graphite—from pencils to atomic bombs.

## SOURCE AND PROPERTIES OF GRAPHITE

**QUES.** Are all graphites—varying in type, purity and particle size—suitable for the same uses?

**ANS.** Definitely not. In nearly every case, each application governs the selection of graphite in type, purity and particle size. Lubricants require the crystalline types of highest purity. Electrical applications usually require high purity. The lower purity grades of natural amorphous graphites find less exacting uses.

**QUES.** What are the characteristics of graphite that make it one of mankind's most useful industrial minerals?

**ANS.** It is extremely lubricous or slippery, lustrous, oil-and-grease-free (unless processed with such), and withstands excessive heat, cold and pressures. It neither destroys nor is destroyed by contact with water, oil or any chemical. It is electrically conductive, heat conductive, non-magnetic, non-fusible, non-toxic, non-odorous and does not permanently stain. It adheres tenaciously to almost all substances and has a low co-efficient of expansion.

**QUES.** What was the first product made from graphite?

**ANS.** Pencils, in 1554.

**QUES.** Is graphite processed into all required forms and shapes that make it usable for innumerable manual, mechanical, chemical, and electrical applications?

**ANS.** Graphite owes its remarkable versatility to its almost unlimited scope of form and formulation. It is available in a wide variety of microscopic powders, large flakes, fluids, non-fluids, concentrates, bars, tubes, sheets, plates and specially processed shapes.

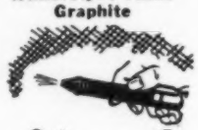
**QUES.** In what products or processes is graphite now principally used?

**ANS.** Lubricants • Pipe joint seals • Mechanical packings • Gaskets • Brake linings • Sand and metallic molds • Lustrous heat-resisting polishes • Protective coatings • Crucibles and refractories • Electronics • Electroplating • Electrodes • Dry batteries • Motor and generator brushes.

A few of thousands of widely used products containing Dixon's Graphites. Those starred are Dixon's products, many of them sold by supply houses everywhere.

★ Ticonderoga Flake Graphites Nos. 1 & 2

★ Microfyne Flake Graphite



Cub . . 15¢

Type 4 . 40¢

★ Graph-Air Guns

Now may we receive *your questions* on how graphite can help *you*?

# DIXON'S GRAPHITES

Products of

JOSEPH DIXON CRUCIBLE COMPANY

Jersey City 3, N. J. Div. 8-Q-7

**LOOK FOR No. 3**

*in this series. We will gladly send you reprints of any you may miss.*

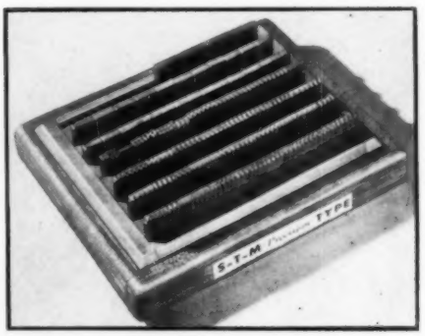

*(Continued from page 123)*

of which are equipped with Towmotor ram accessories to handle open-center loads, handle 15,000-lb loads with ease, operate at maximum capacity 24 hours a day, lifting, transporting and stacking cumbersome loads of sheet, strip and rolled steel. How Youngstown Sheet and Tube Company cut hours and dollars from its handling budget through modern Towmotor Mass Handling technique is told in Towmotor Job Study No. 74, an illustrated, informative analysis of handling operations at Youngstown's Campbell plant. Copies of this report are available, without obligation, to anyone interested in materials handling operations.

## PRECISION STEEL TYPE FOR PRECISION MARKING

A new line of interchangeable steel type, identified as "S-T-M" precision type, designed for stamping steel and other products requiring high grade marking, has been announced by the M. E. Cunningham Company.

The new type is available in condensed, medium, and extended Gothic characters, in sizes ranging from $\frac{1}{32}$ in. to $\frac{1}{2}$ in., in light, medium or bold face styles. The same range of




**This precision type gives deep, clear-cut marks.**

character sizes, widths and type faces are furnished in reverse style for stamping rubber, bakelite, or plastic molds.

Engraved extra deep and on a 25 degree bevel, Cunningham precision type will give deep, clear-cut marks whether the characters are stamped directly into the product, or from the mold to produce a raised letter. It is excellent for plain or roll leaf heat branding of plastic, bakelite, or rubber products, and can be furnished on any size body to suit a specific marking requirement or for use in a special holder or marking machine.

## STUDY ALUMINUM USE IN INDUSTRIAL MACHINERY

▲ An intensive program by Reynolds Metals Company, to develop new uses for aluminum in industrial machinery is resulting in greatly increased interest in aluminum in this field, D. P. Reynolds, vice president, revealed in a statement recently. "Now the company's service to machine builders is being further expanded by enlarging Reynolds development and sales service facilities for these customers," he said in announcing recent additions to this staff.

The past year has seen a tremendous volume of extruded aluminum shapes go into textile machinery where aluminum has proved exceptionally advantageous because its light weight means moving parts can have less inertia, permitting increases in operating speeds, as well as smoother action with less vibration. Shipping costs are cut, too.

Since the extrusion process allows production of almost any conceivable cross section, it is possible to make a single aluminum extrusion that can replace two or more cast iron or steel parts that require machining of adjoining surfaces and subsequent assembly. Considerable savings in cost are thus possible.

Painting is unnecessary as aluminum is rust-free. Thus it requires a minimum of maintenance to keep it spotlessly clean, and moisture condensation cannot cause any stains in the yarns and fabrics being processed.

Many new applications for aluminum in industrial machinery are now being worked out. Already extruded aluminum parts and tubing are replacing steel and iron, often with distinct cost advantages as well as producing a better product.

## FRICTIONLESS SUSPENSION FOR LIFTING MAGNETS

▲ Loads on the larger 55 in. and 65 in. lifting magnets are steadily increasing. This is especially true to the handling of strip steel coils.

Downtown Company has brought out a frictionless suspension made of high alloy steel. This suspension is stronger than suspensions made of iron chain. It avoids the excessive wear due to friction. Each 55 in. suspension is tested to 85,000 lbs and each 65 in. suspension is tested to 115,000 lbs.

# *Book Reviews*

"Manual of ASTM Standards on Refractory Material" brings together conveniently and in their latest approved form all of the some 40 ASTM standard and tentative specifications, classifications, methods of testing, and definitions pertaining to refractories.

Certain other pertinent information of value in the testing and use of refractories, but not in the category of ASTM standards, is also included, such as a suggested procedure for calculating heat losses, a suggested practice for use with ASTM panel spalling tests, suggested petrographic techniques, data on standard samples for chemical analysis, pyrometric cone equivalent determinations and industrial surveys of service conditions of refractories.

New ASTM Tentatives added in the 1948 edition include specifications for castable refractories, a general method of test for thermal conductivity of refractories, a method of test for thermal conductivity of fireclay refractories, and tests for bonding strength and refractoriness of air-setting refractory mortar (wet type).

There is also added an Industrial Survey of Steel Pouring Pit Refractories. The survey of Refractory Service Conditions in Open-Hearth Practice has been revised. Other surveys cover: Electric Steel Furnaces, Malleable Iron Industry, Copper Industry, Lead Industry, By-Product Coke Ovens, Lime Burning Industry, Glass Industry (Continuous Bottle Glass Furnaces, Continuous Plate Glass Furnaces), Portland Cement Industry, Stationary Steam Boilers.

Copies of this Manual, aggregating 264 pages, can be obtained from ASTM headquarters, 1916 Race St., Philadelphia 3, Pa., at $2.50 per copy in heavy paper cover, and $3.15 in cloth.

▲ Hazards to the health of arc welders engaged in steel ship construction are negligible when adequate ventilation is provided to control the toxic fumes released, according to "Health of Arc Welders in Steel Ship Construction." Public Health Bulletin No. 298 just released by the U. S. Public Health Service. The Bulletin reports a study of the health of shipyard welders which was made by the Industrial Hygiene Division, U. S. Public Health Service in cooperation with the U. S. Maritime Commission and the U. S. Navy in Maritime Commission and Navy-contract shipyards.

Single copies of "Health of Arc Welders in Steel Ship Construction," Public Health Bulletin No. 298, by Waldemar C. Dreessen, Senior Surgeon; Hugh P. Brinton, Statistician; Robert G. Keenan, Senior Assistant Scientist (R); Thalbert H. Thomas, Sanitary Engineer (R); and Edwin H. Place, Surgeon (R) of the U. S. Public Health Service; and James E. Fuller, Lt. Comdr. H (S) USNR, Regional Health Consultant, U. S. Maritime Commission, may be obtained from the U. S. Public Health Service, Washington 25, D. C. Additional copies may be purchased from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 55 cents per copy.

▲ "Kinematics of Machines," by Leon Marr Sahag, professor of engineering drawing and design, Alabama Polytechnic Institute, has just been published by the Ronald Press Company, 15 East 26th Street, New York, New York. This book, which is bound in brown cloth, 249 pages, is well illustrated. The price of the book is $4.00.

The book is intended as a basic course for college students and includes all the fundamental material necessary to enable students to enter into their work as engineers working on the design of new and improved machines for use in industry. The book is up-to-date inasmuch as it includes information about motions required in the newer and better machine designs. In the older designs, because the slower speed machines did not require extreme accuracy of methods of solving problems involving velocities, accelerations, and similar factors, the machines as constructed then gave satisfactory service. Today, the high-speed machines in particular require computation of very accurate results of these factors for satisfactory operation. Consequently, adequate information in kinematics, as described in this book, is essential.

# BAKER articulated SHEET-HANDLER loads 200 tons per hour— SAVES $4.30 PER TON *

**LOADING**
**3 minutes per 10-ton pack**

In the warehouse the 10-ton pack, firmly strapped, is conveniently loaded onto the Sheet Handler with the traveling crane.

Entering car, tractor end first, pack No. 1 is loaded on near side of car. Steel plates protect floor against breakage.

Squared away, table is tilted preparatory to discharging load. Note wood-lined corner pieces which prevent damage to sheets.

Winch cables hold the pack as table is tilted until load touches the floor. Truck then backs out from under the pack.

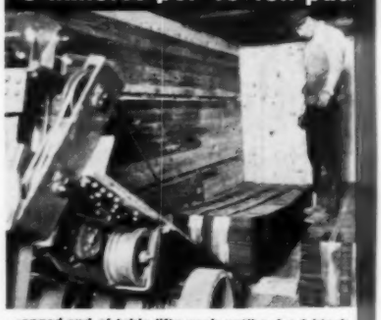
● Cooperating with a large steel mill, Baker engineers worked out this efficient method of handling steel sheets in and out of box cars. By making it possible to load and unload unit packages instead of single sheets, handling costs were cut as much as 87%.

The Baker Truck loads and unload sheets in packages weighing up to te tons, and sizes up to 48" x 144". Beside cutting handling costs and savin time, this method prevents scratchin and other damage to sheets, reducin losses and saving on finishing expens

***ACTUAL SAVINGS RESULTING FROM THE USE OF THE BAKER ARTICULATED SHEET HANDLER**

| | COST PER TON | | |
|---|---|---|---|
| | OLD | NEW | SAVING |
| Damage to sheet chargeable to mill | $1.035 | $0.261 | $0.774 |
| Damage to sheet chargeable to railroad | 2.688 | 0.066 | 2.622 |
| Labor at mill — finishing to cars | .190 | .080 | .110 |
| Labor at receiving — cars to storage | .380 | .030 | .350 |
| Cost of bracing, including return freight on bracing used in new method | .325 | .310 | .015 |
| Maintenance and depreciation — equipment at mill | .050 | .040 | .010 |
| Maintenance and depreciation — equipment at receiving plant | .040 | .030 | .010 |
| Freight car damage | .416 | -- | .416 |
| TOTALS | $5.124 | $0.817 | $4.307 |

**UNLOADING**
**5 minutes per 10-ton pack**



. ronged end of table lifts pack until a 4 x 4 block may be thrust under 2 x 4 runner strips.

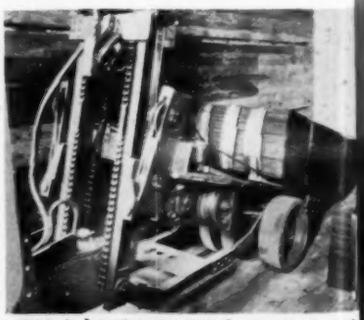


Table is forced under pack by means of winch cables. It is then leveled off and truck leaves car with its 10-ton load.

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OF THE BAKER RAULANG COMPANY
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In Canada: Railway and Power Engineering Corporation, Ltd.

**Baker INDUSTRIAL TRUCK**

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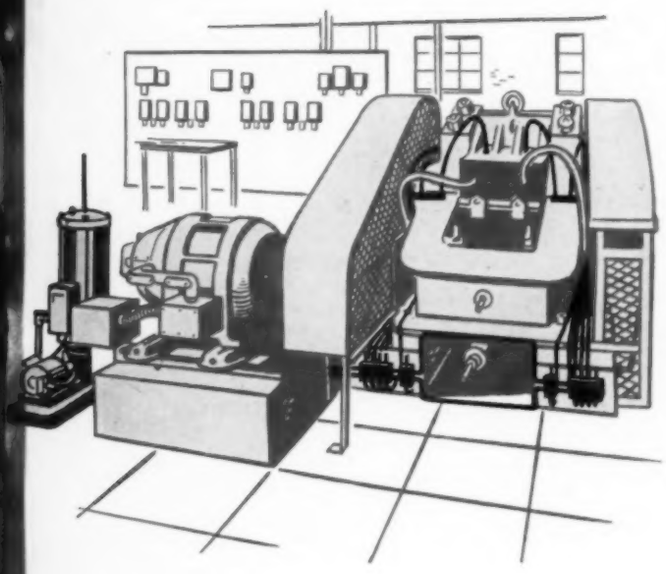
# Stops bearing trouble on six rock crushers by installing Farval



FREQUENT bearing failures interfered seriously with production in an ore preparation plant. The material processed was an extremely hard flint-like rock, which not only generated tremendous bearing pressures in the crushers, but created a highly abrasive dust as well. Various methods of lubrication were tried, including drip systems, wick feeds, grease cups, and automatic oil cups. Many of these devices plugged up with dirt. Dust got into bearings and quickly ruined them, resulting in continual shutdowns for bearing replacement.

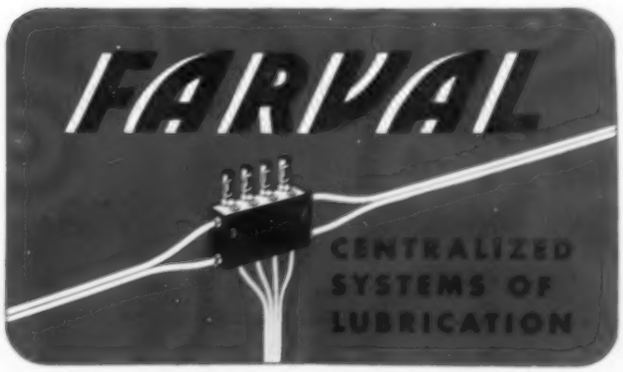
Finally, a Farval centralized lubrication system was installed on one crusher. It stopped the trouble. It was so successful that Farval systems were installed on the five other crushers. Now the swing jaw, Pitman and main eccentric shaft bearings on each crusher all receive adequate, automatic lubrication. There have been no bearing failures since Farval was installed.

Farval delivers oil or grease under pressure to a group of bearings from one central station, in exact quantities, as often as desired. It does its work while the machine is in operation. Farval —the Dualine System with the Positive Piston Displacement Valve—that has but 2 Moving Parts—is Fully Adjustable—and with a Tell-tale indicator at each bearing to show the job is done.

Write for Bulletin 25 for a full description of Farval. The Farval Corporation, 3278 East 80th Street, Cleveland 4, Ohio.

*Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.*

FARVAL—*Studies in Centralized Lubrication No. 104*



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Six years ago, the Bell Aircraft Corp. installed in its Buffalo plant many machine tools which had G-E Tri-Clad motors tucked away inside. Operating in confined quarters where the volume of cooling air was limited (and laden with oil), these sturdy Tri-Clads toiled 24 hours a day, 7 days a week all through the war years. At a time when manpower for motor maintenance was almost unobtainable, these motors proved they had the "stuff" to stay on the job with only the barest amount of attention.

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